National Aeronautics and Space Administration

HUMAN RESEARCH PROGRAM

2011 Fiscal Year Annual Report

Preparing for human exploration

THIS FISCAL YEAR WITNESSED THE SUCCESSFUL RETIREMENT OF THE SPACE SHUTTLE PROGRAM and the further development of NASA's strategic direction for Human Spaceflight. For the Human Research Program (HRP), FY2011 was a year of continued effective performance in which we delivered several key research products that will help take human space explorers far beyond low Earth orbit. Our research portfolio evolved to invest more in areas that use the unique capabilities of the ISS and de-emphasized areas that focused on previously planned lunar missions. In FY2011, HRP expanded its international presence by organizing and hosting the 18th International Astronautics Academy's Humans in Space Symposium in Houston and also developing and leading the execution of a highly successful multi-national outreach program called "Mission X." This unique program, inspired by astronaut training, brought together 14 space agencies and partner institutions from around the world to address health and fitness education in young people.

The many outstanding products described in this report are applicable not only to lunar and Mars landing missions, but also human missions to near-Earth asteroids, Lagrange points, or a Mars fly-by. When applying our risk mitigation approach, the Human Research Roadmap, to these new mission profiles, it becomes very clear that the knowledge, research and evidence that frames the HRP will be a key driver in the success of these missions. HRP worked closely with the Human Space Flight Architecture Team to ensure consistency between our research and technology efforts and the missions, architectures, and vehicles that are included in the human exploration options.

> "The Human Research Program will... stay **FOCUSED** on the most **SIGNIFICANT** problems to **ENSURE** a highly **SUCCESSFUL** human space **EXPLORATION** program."

With the extension of the International Space Station (ISS) program to 2020, HRP is well positioned to increase the use of the ISS as a research platform to understand and solve many of the issues that confront humans on exploration missions. Our research in areas such as radiation, exercise, nutrition, and lighting will make exploration missions healthier, safer, and more productive. The Program is making extensive use of the ISS to address the issues of maintaining human health and performance during and after long-duration spaceflight. In FY2011, we added new ISS capabilities with the addition of the second generation Ultrasound-2, the Urine Monitoring System, and the Muscle Atrophy Research and Exercise System – a joint ESA/NASA development. Human research for space exploration is one of the most active U.S. research areas on the International Space Station.

This year saw the formation of a new HRP project to address an emergent medical condition observed in several ISS crewmembers. NASA flight surgeons have observed changes in crewmembers' vision and intracranial pressure. These changes may permanently affect vision and hold the prospect of increased lifetime risks due to chronically elevated intracranial pressures. The consequences of this problem would, if left unchecked, inhibit missions longer than six months. HRP, working in concert with the JSC Space Medicine Division, has devised a research plan to understand the causes of this problem and develop prevention techniques.

Through our established management tools, we continue to monitor our progress and solicit feedback from external advisors and the scientific community, thereby continually improving and strengthening the Program. HRP remains engaged with the space life sciences research and technology communities through two NASA Research Announcements, a Small Business Innovative Research solicitation, as well as sponsoring innovation challenges, workshops and working groups.

The Human Research Program will continue to leverage off our organizing framework, produce research and technology results, and stay focused on the most significant problems to ensure a highly successful human space exploration program.

Dennis J. Grounds
Program Manager

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Background

Crew health and performance are critical to successful human exploration beyond low Earth orbit. Risks to health and performance include physiologic effects from radiation, hypogravity, and planetary environments, as well as unique challenges in medical treatment, human factors, and support of behavioral health. The scientists and engineers of the Human Research Program (HRP) investigate and reduce the greatest risks to human health and performance, and provide essential countermeasures and technologies for human space exploration.

In its sixth year of operation, the HRP continued to refine its management architecture of evidence, risks, gaps, tasks and deliverables, and provided products to support the preliminary design of new space flight vehicles. Experiments continued on the International Space Station (ISS), on the ground in analog environments that have features similar to those of space flight, and in laboratory environments. Data from these experiments furthered the understanding of how the space environment affects the human system. These research results contributed to scientific knowledge and technology developments that address the human health and performance risks.

As shown in this report, HRP has made significant progress toward developing medical care and countermeasure systems for space exploration missions which will ultimately reduce risks to crew health and performance.

Goal and Objectives

The goal of the HRP is to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. These are the specific objectives of the HRP:

1) Develop capabilities, necessary countermeasures, and technologies in support of human space exploration, focusing on mitigating the highest risks to crew health and performance. Enable the definition and improvement of human spaceflight medical, environmental and human factors standards.

2) Develop technologies that serve to reduce medical and environmental risks, to reduce human systems resource requirements (mass, volume, power, data, etc.) and to ensure effective human-system integration across exploration mission systems.

3) Ensure maintenance of Agency core competencies necessary to enable risk reduc-

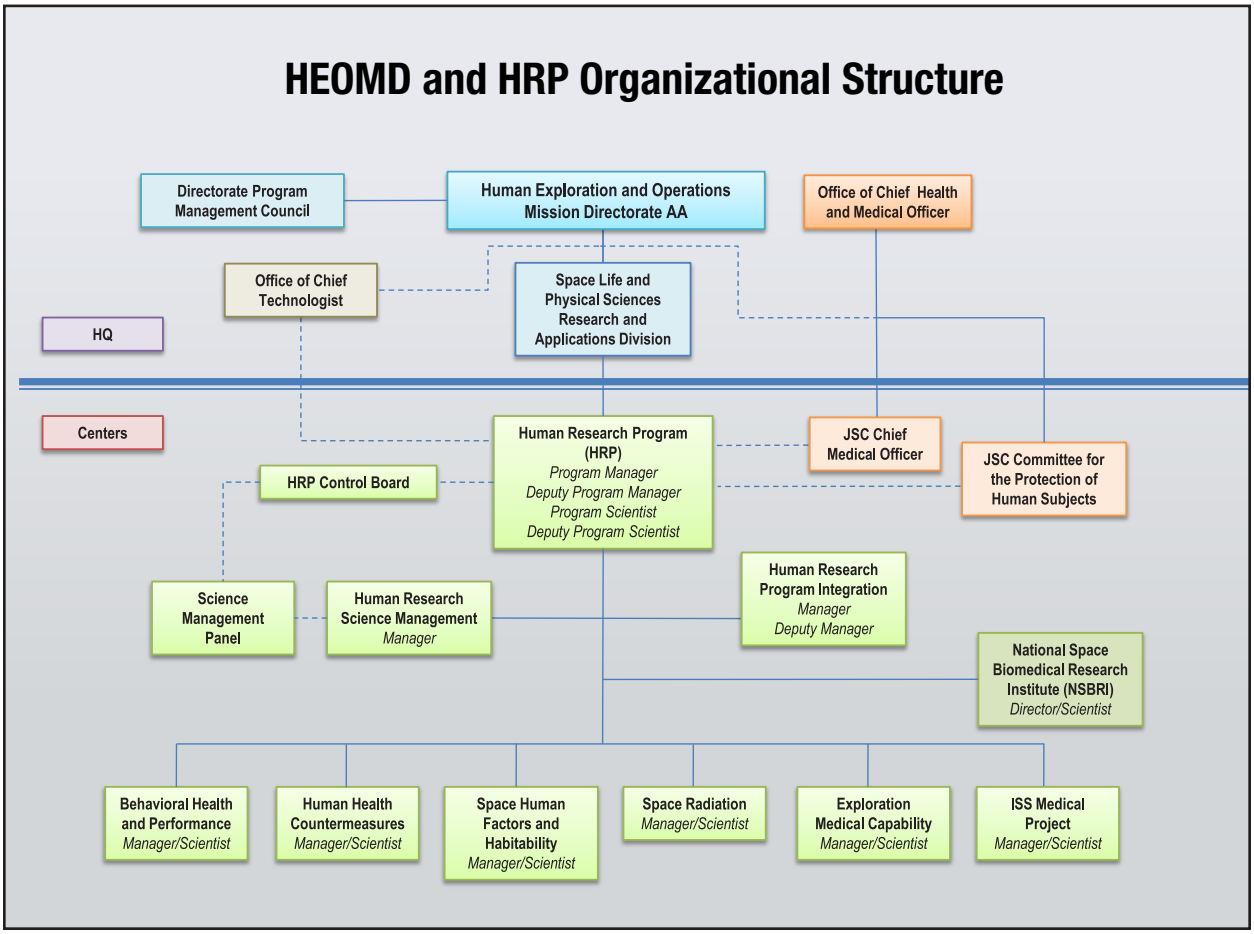
tion in the following areas: space medicine, physiological and behavioral effects of long duration spaceflight on the human body, space environmental effects, including radiation, on human health and performance and space human factors.

Program Organization

The HRP's organization is designed to support and accomplish the goals of the Human Exploration and Operations Mission Directorate (HEOMD) and NASA's Office of the Chief Health and Medical Officer (OCHMO). To that end, HRP conducts research and develops technology that enables the OCHMO to establish and maintain NASA-wide human health and performance standards. Furthermore, HRP provides HEOMD with methods of meeting those standards in the design, development, and operation of technological systems for exploration missions.

Organizationally, HRP resides within the HEOMD; however, the management of HRP is located at the Johnson Space Center. The HRP Program Manager and Deputy Manager lead all aspects of the program and the HRP Program Scientist and Deputy Scientist lead the science management and coordination. Two offices support program and science management and provide integration across the Program. There are six Elements that comprise the Program and are focused to accomplish specific goals for investigating and mitigating the highest risks to astronaut health and performance.

The Science Management Office (SMO) and Program Integration Office (PIO) provide coordination of HRP activities in support of the Program

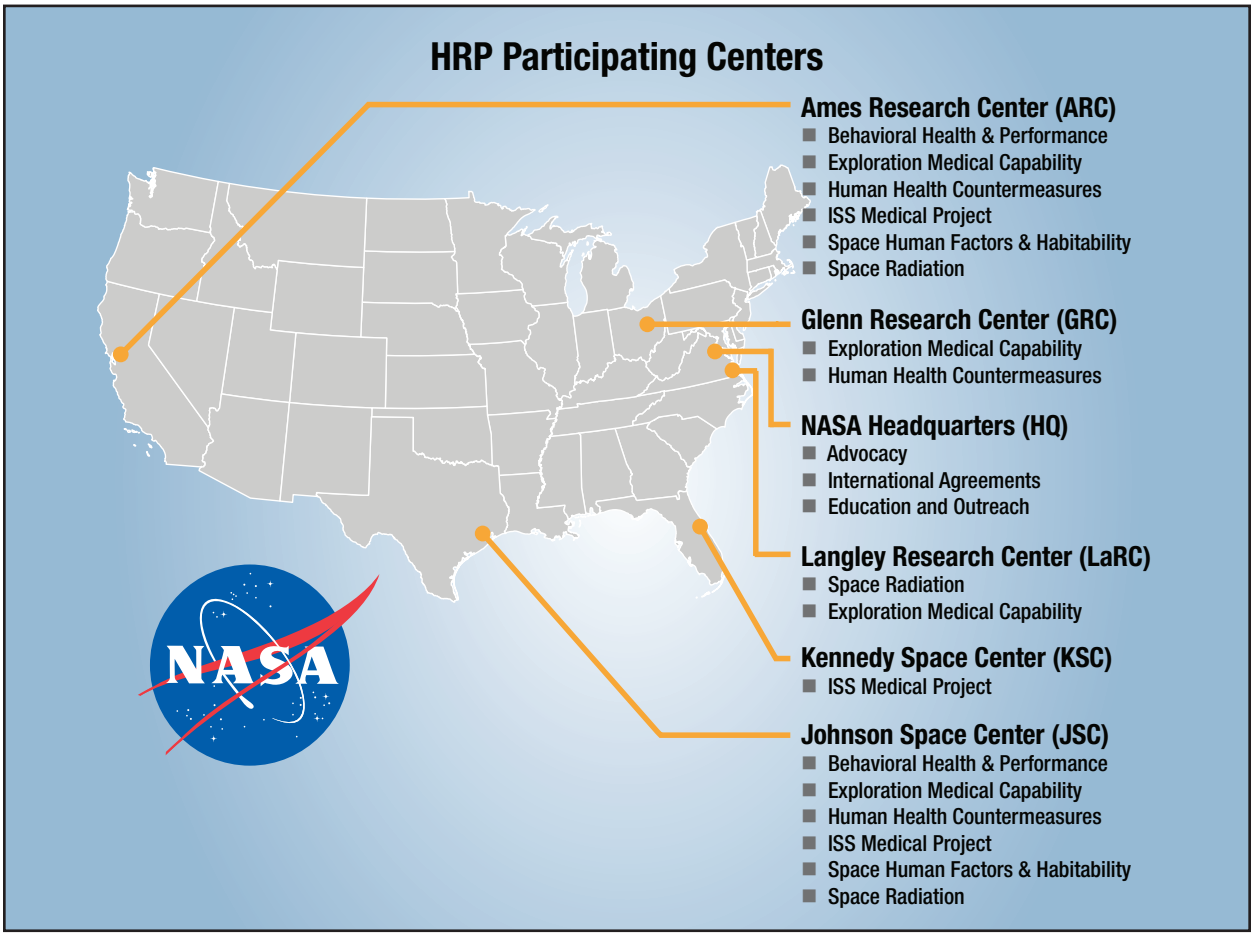


Manager, Program Scientist, and all other Program components. The SMO maintains scientific integrity of the HRP's research, reviews and integrates science tasks, reviews the prioritization and implementation of flight and ground analog tasks, communicates research needs to other NASA programs and cultivates strategic research partnerships with other domestic and international agencies. The PIO provides program planning, integration, and coordination across the HRP. This office ensures close coordination of customer needs and the HRP's deliverables developed to meet those needs.

Six subject areas or Elements comprise the HRP: International Space Station Medical Project, Space Radiation, Human Health Countermeasures, Exploration Medical Capability, Space Human Factors and Habitability, and Behavioral Health and Performance. These Elements provide the HRP's knowledge and capabilities to conduct research to address human health and performance risks of spaceflight, and they advance the readiness levels of technology and countermeasures to the point where they can be transferred to the customer programs and organizations. Each Element consists of related projects and research tasks focused toward developing products that reduce the highest risks in that area. To learn more about the HRP Elements, please visit: http://www.nasa.gov/exploration/humanresearch/elements.

Partnerships and Collaborations

The HRP works with universities, hospitals, and federal and international agencies for the purpose of sharing research facilities and multi-user hardware, and for collaboration on research tasks of mutual interest. The HRP uses bed rest facilities at the University of Texas Medical Branch in Galveston, Texas,



to study changes in physiologic function associated with weightlessness. Many of these changes occur in people subjected to bed rest with the head tilted downward at a 6 degree angle.

The NASA Space Radiation Laboratory (NSRL) at the Department of Energy's Brookhaven National Laboratory in Upton, New York conducts research using accelerator-based simulations of space radiation. The HRP also utilizes radiation research facilities at the Loma Linda University Medical Center in Loma Linda, California.

The National Space Biomedical Research Institute (NSBRI), an academic institute funded by the HRP, investigates the physical and psychological challenges of long-duration human spaceflight. Founded in 1997 through a NASA competition, the NSBRI is a nonprofit research consortium that connects the research, technical, and clinical expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA.

In June 2011, NSBRI moved into a new Consolidated Research Facility (CRF) which is located in the BioScience Research Collaborative (BRC) at Rice University. Additional information about the NSBRI can be found at: www.nsbri.org.

The HRP also maintains collaborative relationships with the ISS International Partners through various working groups. These relationships enhance the research capabilities of all partners and provide synergism of research efforts.

Brookhaven National Laboratory covers 5,265 acres and is located in Upton, New York. The NSRL conducts research at Brookhaven using accelerator-based simulations of space radiation.

Examples of Partnerships and Collaborative Relationships with Universities, Industries, and Government Agencies

Examples of HRP Partnerships and Collaborations	Benefits to Exploration
National Space Biomedical Research Institute	Academic institute which investigates the challenges of long-duration human spaceflight and bridges the expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA
International Space Life Sciences Working Group (Canada, Japan, Germany, Ukraine, France, and the European Space Agency)	Provides coordination of international development and use of spaceflight and ground research facilities by identifying mutual interests and compatibilities, enhancing communication, and encouraging a unified effort among participating space life sciences communities around the world
US-Russian Joint Working Group	Enhances research capabilities and provides synergy in operations and optimal use of the ISS
National Institutes of Health, Department of Energy, Centers for Disease Control and Prevention, Department of Agriculture, Department of Defense	State-of-the-art research facilities, research activities, and technology development of mutual interest
General Clinical Research Center and the Lerner Research Institute at the Cleveland Clinic/University of Washington	Provides facilities for bed rest and 6 degree head-down-tilt simulation along with a zero-gravity locomotion simulator in support of HRP research
NASA Extreme Environment Mission Operations (NEEMO) at the Aquarius Undersea Habitat and other analog environments such as Antarctica and Devon Island	Research performed in analog environments in the areas of physiologic adaptation, medical technology, and behavioral health and performance
University of Texas Medical Branch, Galveston, TX	Provides bed rest facilities to study changes in physiologic function associated with weightlessness
Department of Energy - Brookhaven National Laboratory	State-of-the-art facility conducts research using accelerator-based simulation of space radiation
Loma Linda University	Space radiation research and facilities
European Union in Radiobiology Research Program	Space radiation research
International Council of Radiation Protection	Recommendations for radiation protection in space
Massachusetts Institute of Technology Man-Vehicle Laboratory	Working to define the role of the human in complex space systems

Examples of HRP Partnerships and Collaborations	Benefits to Exploration
Texas Instruments	Under the HRP Education and Outreach and Texas Instruments Education Division NASA Space Act Agreement, a virtual math camp was held and new content was developed for the Math and Science @ Work and Exploring Space Through Math projects
American Association of Retired Persons Convention; Hispanic Engineering, Science, and Technology Week; National Space Symposium; NASA Day on the USS Intrepid; NASA-on-the-Hill	Allowed for public dissemination of information on the Human Challenges of Space Exploration

The HRP organizes and participates in international collaborative meetings and coordinates research and technology workshops. The workshops are conducted to inform researchers outside of NASA about the HRP's research and to obtain information about research going on outside of NASA.

International Coordination Meetings and Research and Technology Workshops

Meeting	Meeting Description
International Space Life Sciences Working Group (ISLSWG) http://www.nasa.gov/exploration/about/islswg.html	Works to bring agencies together by identifying their mutual interests and programmatic compatibilities, enhancing communication, and encouraging a unified effort among the participating space life sciences communities around the world
Meeting of the US-Russian Joint Working Group	Discussed space biology and space medicine emphasizing ISS research and opportunities for collaboration, and education and outreach opportunities to inspire the next generation of scientists and physicians who will work in future human spaceflight endeavors
62nd International Astronautical Congress http://iac2011.com/	Shared information about space for human benefit and exploration, and provided information on HRP Education and Outreach activities
22nd Annual NASA Space Radiation Investigators' Workshop http://www.dsls.usra.edu/radiation2011	Provided an opportunity for active researchers in the NASA Space Radiation Program to share the results of their work and to explore new directions of research that may benefit the NASA program
18th International Academy of Astronautics Humans in Space Symposium http://www.dsls.usra.edu/meetings/IAA	International scientific symposium dedicated to discussion and research in the human and biological sciences related to long-duration space travel

Meeting	Meeting Description
Near-Earth Asteroid Telemedicine Workshop	ExMC hosted workshop. Documented medical operations concept for crewed mission to an near-Earth asteroid (NEA), determined gaps between current capabilities and the capabilities outlined in the operations concept document, identified research required to close the gaps, discussed potential collaborations with external-to-NASA organizations
From Mice and Men to Earth and Space	Joint NASA-National Cancer Institute Workshop on Lung Cancer Risk Resulting from Space and Terrestrial Radiation
International Collaboration on Analog Utilization Workshop http://www.dsls.usra.edu/meetings/IAA/analog	The goal of the workshop was to develop a collaborative international analog framework. This new network will address long duration space flight, human health, and performance risks.
Net Habitable Volume Workshop	The goal of the workshop was to develop a response to the NASA Human Exploration Framework Team on how to address the "habitable" and "net habitable" volume necessary for long-duration human spaceflight missions by identifying both the design issues, as well as the psychological issues that will impact the human.

Improved Human Research Roadmap Web Content Management System

The HRP Integrated Research Plan (IRP) is the HRP's strategic and tactical plan for research. The Human Research Roadmap (HRR) was developed as a publicly accessible, searchable, and user-friendly web-based version of the IRP. The IRP uses a structured architecture that ties evidence to risks, risks to knowledge gaps, knowledge gaps to tasks, and tasks to deliverables. The HRR website provides the capability to search this architecture for items such as gaps associated with a risk, tasks associated with a given gap, and their associated deliverables.

In FY2011, HRP enhanced the Roadmap's usability by putting into effect an improved web-based Content Management System (CMS) that allows risk owners to directly update their research plan content. The CMS also includes an improved mapping of both risks to knowledge gaps and gaps to tasks.

In addition, the site's content was expanded to house research schedules and evidence reports for risks. These improvements enabled the HRR CMS to be used – for the first time – to collect and review updates to IRP content while the Plan was under configuration management control. The Roadmap can be accessed at the following public website: http://humanresearchroadmap.nasa.gov.

HRP Co-Hosts the 18th IAA Humans in Space Symposium

The HRP, along with the Universities Space Research Association, the National Space Biomedical Research Institute (NSBRI), Wyle Integrated Science and Engineering Group, the University of Houston, and the NASA JSC Engineering Directorate, Systems Architecture and Integration Office, hosted the 18th International Academy of Astronautics (IAA) Humans in Space Symposium, which was held in Houston, Texas, April 11-15.

Over 500 registrants from over 15 nations participated in the symposium. Opening ceremonies featured welcoming remarks from the Symposium Chair, the Chancellor of the University of Houston

A highlight of the 18th IAA symposium was a concert of spaceflight-related music performed by local students.

The HRP Program Scientist and local IAA Committee Chair addresses the IAA during the Opening Ceremony for the 18th Humans in Space Symposium.

System, the JSC Center Director, and a representative of the Secretary General of the IAA. Dr. Joseph Kerwin, the first U.S. physician in space, was the keynote speaker. The audience was also treated to a display of award-winning art and music, related to spaceflight, by youth from around the world, with the winning musical compositions performed in a concert by the Clear Lake High School Orchestra.

The scientific program consisted of panel sessions on special topics of interest in the mornings, followed in the afternoons by poster presentation sessions (including a Graduate Student Poster Competition), which provided opportunities for the registrants to interact with the presenting scientists. Attendees took advantage of the numerous opportunities to meet for in-depth discussions. Several of the morning panel sessions commemorated the 50th anniversary of the first human space flight by Yuri Gagarin and the 30th anniversary of the first space shuttle flight. Special educational presentations were held in the evenings. The meeting program and abstracts can be viewed at http://www.dsls.usra.edu/meetings/IAA.

New Research Solicitations and Selections

HRP's priority is to promote full and open competition for research and technology investigations through periodic research solicitations issued by both NASA and NSBRI. Additionally, their priority is to maintain a balance between the selection of internal to NASA investigations and external investigations. When research results are needed quickly or studies are heavily embedded with mission operations, the HRP may use directed research investigations to accomplish the desired research. Currently, 78% of research tasks are derived from open competition, while 22% are directed research.

The 2010 NASA Research Announcement (NRA) for **"Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions"** jointly solicited proposals for NASA and NSBRI. Proposals were solicited in the areas of host-microbe interactions, crew microbiome, workload measures, habitability concept tools, psychosocial aspects of food, cognitive performance, autonomy, behavioral health, muscle, nutrition and exercise, immunology, space motion sickness, fracture healing, and suit injury countermeasures.

In addition, proposals were solicited by NSBRI in the areas of cardiovascular alterations, human factors and performance, musculoskeletal alterations, neurobehavioral and psychosocial factors, sensorimotor adaptation, and smart medical systems and technology. Peer review of the 51 NASA Step-2 proposals and 34 NSBRI Step-2 proposals submitted in response to the solicitation occurred in February 2011. Eleven awards were announced in April 2011 with nine of the principal investigators of these studies joining HRP and two joining NSBRI's team-based research program.

The 2011 NRA for **"Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions"** was released on August 23rd and jointly solicited proposals for HRP and NSBRI. For this solicitation, special emphasis was placed on the high-priority research area of visual impairment and intracranial pressure. To address this, proposals were solicited by HRP in the areas of visual acuity, ocular structure and function, and fluid distribution.

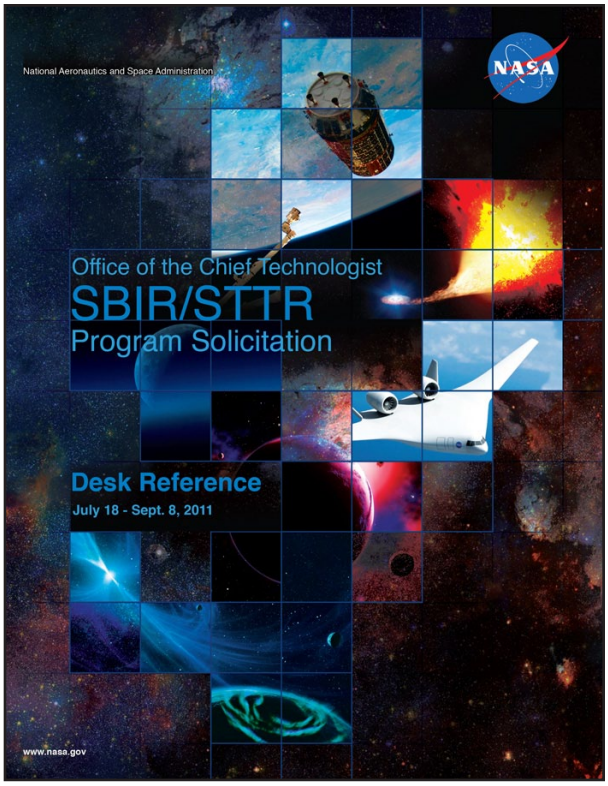
Additionally, proposals were solicited in the areas of team social, technical, and task roles as well as the effects of constrained communication on operational tasks. HRP also requested proposals for short-term investigations or technologies that provided innovative approaches to any of the risks defined in the Integrated Research Plan.

Proposals were solicited by NSBRI in the areas of microgravity-induced visual alterations and intracranial pressure, cardiovascular alterations, human factors and performance, musculoskeletal alterations, neurobehavioral and psychosocial factors, sensorimotor adaptation, and smart medical systems and technology. A total of 202 Step-1 proposals were received in September, an increase from 159 received in FY2010. Final NRA selections will be announced in April 2012.

The NRA **"Ground-Based Studies in Space Radiobiology"** was released in January 2011. It solicited proposals for ground-based research in the areas of high-energy particle (HZE) nuclei risk assessment; radiation quality and carcinogenic processes; and central nervous system risks from space radiation.

Proposals were solicited in the area of space radiation biology to use beams of high-energy heavy ions to simulate space radiation at the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory. A peer review was conducted in July to evaluate 51 Step-2 proposals. Seven awards were announced in August.

The NRA **"NASA Specialized Centers of Research (NSCORs) & Virtual NSCOR (VNSCOR) for Space Radiation Solid Cancer Risks and Biological Countermeasures"** was released in April of 2010. Proposals for ground-based research were solicited in the area of space radiation biology to use beams of high-energy heavy ions to simulate space radiation at NSRL. This research is expected to provide the basis for improved estimation and uncertainty reduction for the risk of solid cancer resulting from space radiation exposure, with the additional goal of developing cutting-edge approaches to biological countermeasures for solid cancer risks from exposure to high-mass, high-energy (HZE) nuclei. Review panels met to evaluate 16 Step-2 proposals and five awards were announced in October 2010.



The Small Business Innovation Research (SBIR) Program is a highly competitive three-phase award system which provides small businesses with opportunities to propose innovative ideas that meet specific research and development needs.

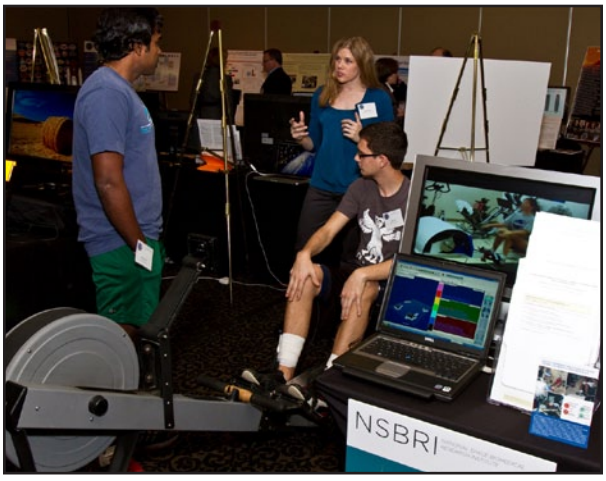
The NASA Small Business Innovation Research (SBIR) Program Management Office released the 2011 SBIR Phase 1 Solicitation in July. The six HRP topics included in the solicitation were exploration crew health capabilities, exploration medical capability, behavioral health and performance, space human factors and food systems, space radiation, and in-flight biological sample preservation and analysis. Proposals were reviewed and awards were announced in November. Also, six HRP 2009 SBIR Phase 2 awards were announced in October 2010. For the 2010 Phase 1 cycle, 18 HRP awards were announced in December 2010.

Independent Committee Recommends an Additional Five Years of Funding for NSBRI

In 2011, the National Space Biomedical Research Institute (NSBRI) underwent an extensive assessment of its science programs and operations, conducted by an independent, external, five-year review committee. NASA conducts an external review of the NSBRI every five years to review progress and make recommendations on exercising another 5-year option on the Cooperative Agreement. The panel's findings were reported to NASA as a summary of the performance and progress of NSBRI during the past five years. The committee's overarching, principal recommendation was that NSBRI be funded for an additional five years, based on the achievements and accomplishments of the Institute.

The committee met in Houston in January of 2011 to receive presentations from NSBRI management and leaders of the Institute's science and education program teams. Committee members spoke directly with NSBRI researchers, educators, and trainees and were able to evaluate first-hand many NSBRI science and technology projects and educational programs.

The committee applauded NSBRI's successful response to changing NASA priorities. Impressed with the research being conducted by NSBRI teams, the reviewers emphasized the benefits and increasing importance of multidisciplinary team science for addressing the complex demands of supporting human life in space. The committee also highlighted the unique value of NSBRI which, as a non-governmental organization, can participate in biomedical research and spaceflight-related activities not available to NASA. NSBRI is incorporating the recommendations of the five-year review committee as it moves ahead in its mission to ensure health in space and improve life on Earth.



Incorporating three NSBRI projects, an exercise program of rowing plus strength training was demonstrated during NSBRI's Five-Year Review.

Researchers demonstrated and discussed their work as a part of the NSBRI Five-Year Review.

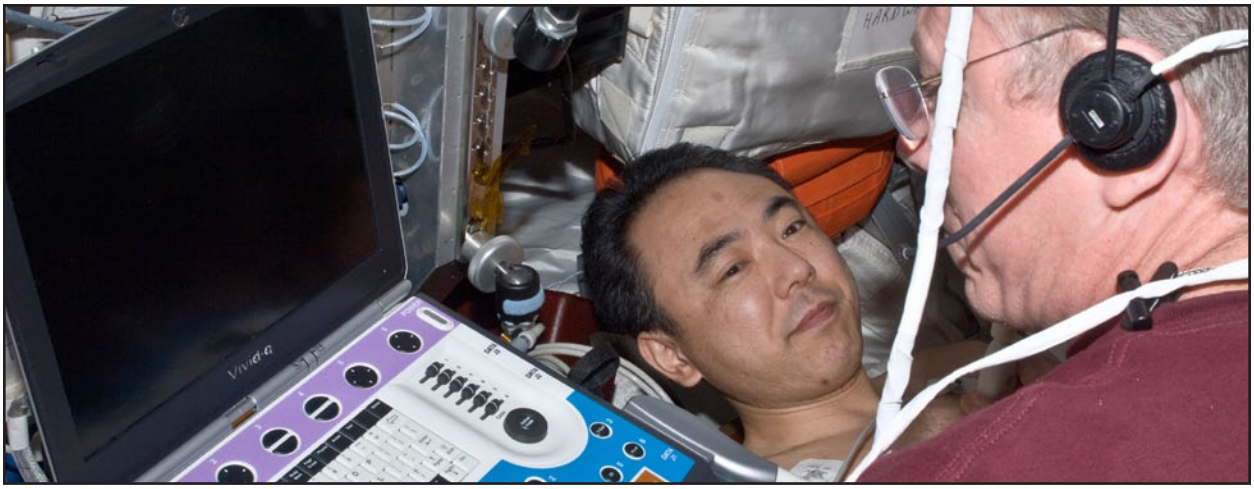
Fourteen Space Agencies Participate in Pilot "Mission X" International Challenge

An expansion of the HRP Education and Outreach Fit Explorer (FE) curriculum occurred with the advent of the first international fitness challenge, Mission X: Train Like an Astronaut. Eleven countries participated in this pilot event between January and March 2011. Eighteen physical fitness and educational activities were used during Mission X, which reached about 100 educators and over 4000 students worldwide.

A student participates in a stacking exercise to simulate the difficulties astronauts face when performing tasks while wearing an Extra-Vehicular Activities (EVA) suit. Train Like an Astronaut uses activities like this to engage young students in physical and mental challenges.

The closing event for the U.S. team, "Hometown Hullaballoo," was held in College Station, Texas, with more than 800 fourth-graders. The day's events included Mission X activities, the NASA exhibit trailer, astronauts, and many displays and activities.

At the conclusion of the Mission X 2011 pilot, data from post surveys were compiled into a final report. The report addresses key findings, lessons learned, statistics on the participants, and recommendations for future challenges.



National Academy of Science to Review Updated Radiation Cancer Risk Model

The newly released NASA Space Radiation Cancer Risk Model incorporates a new recommendation that persons exposed occupationally to space radiation be categorized by their smoking history. This is due to the significant impact of tobacco usage on cancer risk estimates. Since most astronauts are lifetime non-smokers, their risks from radiation are projected to be substantially less than estimates from the National Council on Radiation Protection and Measurements and others, using the U.S. average.

These new estimates of cancer risks from radiation were reviewed and published in the journal *Radiation Research*. Because the NASA Space Radiation Cancer Risk Model is used to project the cancer risk for current ISS crews and trade studies for future exploration missions, the model requires independent review and validation. The National Academy of Sciences (NAS) was recently charged with this task.

Other updates to the model include a revision of coefficients for cancer risk from low-LET (linear energy transfer) radiation based on cancer incidence data; changes in the dose and dose-rate effectiveness factor (DDREF); evaluation of distinct quality factors for solid cancers and leukemia; and replacement of LET dependence with charge and energy dependence. Additionally, updates to the model will incorporate revised uncertainties for low-LET human data, space environments and organ exposures, and radiation quality factors.

The NAS committee will evaluate the proposed updates, taking into consideration the existing knowledge of low-LET radiation cancer epidemiology as well as current uncertainties in quality factors, DDREFs, and organ dose assessment. A draft report to NASA from the NAS committee is expected in the spring of 2012.

Urine Monitoring System and Ultrasound 2 Delivered to ISS

The Urine Monitoring System (UMS) and Ultrasound 2 were delivered to the ISS in FY2011, with the Ultrasound 2 arriving ahead of schedule. Both devices were successfully installed and will support human research investigations.

The UMS accurately measures urine void volume and allows urine samples to be collected for post-flight analysis. Urine samples provide information about the health of crewmembers, enable scientists to use non-invasive methods to assess human physiology during spaceflight, and are critical for validating countermeasures. The presence of the UMS also increases the likelihood of future investigations that require urine samples and will allow for the addition of technologies for real-time sample analysis. Also,

the UMS offers a more convenient method for the collection of urine and the acquisition of in-flight samples requiring return to Earth for analysis and provides more timely results to investigators and feedback about crew health to medical personnel.

The Ultrasound 2 provides high-resolution ultrasound images of target areas in the human body and is used to support a variety of medical and research investigations including bone, cardiac, muscle, blood vessel, and blood flow analyses. The unit works in conjunction with the Human Research Facility Video Power Converter, providing the capability of real-time ultrasound video downlink. This real-time video downlink allows crewmembers to be guided remotely from the ground. This method significantly reduces preflight crew training time and produces better images for research or medical use.

The Ultrasound 2 was deployed ahead of schedule after an unrecoverable failure occurred in the original ISS Ultrasound device during in-flight operations in January 2011. At the time of the failure, the Ultrasound 2 was in development but not scheduled to be delivered to the ISS for more than a year. The

A NASA astronaut uses the Ultrasound 2 to scan the heart of a fellow ISS crewmember.

The Urine Monitoring System is integrated into the Waste Hygiene Cabin on the ISS.

ISSMP team at Ames Research Center and Johnson Space Center accelerated the development and testing of the device in time for the STS-135 launch in July of 2011.

International Space Station to Serve as Future Testbed for Analog Research

The ISS Program Office chartered the International Space Station Testbed for Analog Research (ISTAR) Integrated Product Team with HRP participation in 2010 to plan and implement a set of targeted investigations, technology development, and tasks aboard the ISS. Using the ISS as a high-fidelity analog will provide an environment to address the risks and challenges facing astronauts on long-distance voyages to near-Earth asteroids, Mars, and other destinations beyond low Earth orbit.

This project is unique in that it uses the ISS not as the targeted mission, but as an analog for future long-duration, highly autonomous interplanetary transits. The ISS provides operational and psychological factors not available in other analogs, including astronaut personnel undertaking spaceflight operations in the actual space environment with real risks and stresses.

CPR in microgravity is a challenge to crewmembers who must secure themselves with a strap to deliver adequate chest compressions. ISTAR simulations expand our knowledge for future long duration missions with limited or no communication with the ground.

Using ISS as a test platform, ISTAR allows NASA to continue to document the effects of space flight factors, especially weightlessness and confinement, on the human body and mind, and test treatments to protect against them. It also provides preparations for autonomous operation of astronauts on deep-space missions and begins preparing personnel on the ground for the unique challenges of supporting missions that are out of communication range for immediate guidance and intervention. Additionally, the platform provides the opportunity to evaluate new technologies as they become available.

ISTAR will conduct its first simulation of an exploration mission onboard the ISS during the summer of 2012. That mission will last up to 30 days and will include new HRP-developed space technologies as well as medical and behavioral experiments, such as artificially imposed communication delays between ISS crew members and NASA's Mission Control. Future ISTAR missions in the project's expected 5-year lifespan could last as long as six months.

Spinal Elongation Study Leads to Design Recommendations for Future Vehicles

Many physiological conditions, such as spinal elongation, fluid shifts, bone atrophy, and muscle loss, occur when a person is exposed to microgravity. Specifically, spinal elongation occurs when the lack of gravity and compression on the spinal column allows the natural spinal curve to straighten which results in changes in crewmember height. This change in height can affect crewmember safety during violent maneuvers or a crash landing by reducing the safe clearance between body and structure. Therefore, obtaining accurate measurements of a crewmember's seated height in microgravity is valuable to allow vehicle and habitat designers to provide adequate margin for this growth.

The intent of spinal elongation research is to collect seated height data for subjects exposed to microgravity, provide information about the rate of change in seated height over time, and provide information about clearance requirements for seated height to designers of future vehicles.

Spinal elongation measurements were obtained by measuring the seated height of the crewmembers after the crew had been in space for at least three days.

Data was collected from 29 ISS and shuttle crewmembers and included digital pictures and seated height measurements taken before, during, and after flight. Additionally, stature measurements were obtained from 23 of the 29 crewmembers. The results showed that participating crewmembers experienced growth up to 6% in seated height and up to 3% in stature. A recommended growth allowance of 6% for seated height, based on the analysis of the subject data, will be provided to vehicle designers as the necessary seated height adjustment to allow for crew exposure to microgravity.

Workshop Held to Increase Understanding of Spaceflight Habitat Minimal Volume

The Net Habitable Volume (NHV) Workshop was held April 2011, in Houston, Texas, and brought together a multidisciplinary group of experts in the medical sciences and human habitability and design. The workshop convened to broaden the understanding of requirements for minimal habitable volume for long-duration space missions and the factors that lead to those requirements. Although studies focused on confinement and spaceflight analogs have led to the guidance found in current standards, determining the full story for adequacy of the volume for long-duration missions can be a complicated endeavor. Participants sought an improved understanding of the relationship between behavioral and psychosocial factors and internal volume of a spacecraft.

Workshop attendees identified psychological stressors that affect volume and layout considerations. The stressors were then organized into the following categories: allocation of space; workspace; general and individual control over the environment; sensory monotony; social monotony; crew composition; physiological and medical stressors; and contingency. They then identified known mitigations, in layout, design, and requirements, which were folded into the latest round of mission studies.

The recommendations by workshop attendees for potential future mitigations and research to validate them are being used to plan future research. Although some tasks in the research plan are highly dependent on the chosen exploration strategy and mission, other overarching areas of research were identified that will need to be pursued. These include long-duration confinement and isolation studies analogous to the desired exploration missions and a focus on characterizing psychological stressors and the social dynamic between crewmembers.

Artist concept for a habitat that could support missions to deep space. Habitable volume is a critical factor in designing living spaces for crews on long-duration missions.

Additionally, research on reconfigurable spaces and crew accommodations is recommended. Also, a need for research was identified regarding the development of methods or vehicles that would allow the testing of scenarios not possible with the ISS.

Lighting on ISS Modified to Improve Crew Performance

Numerous studies have shown that bright light – when administered appropriately – provides a potent, safe, reversible, and non-pharmacological countermeasure to facilitate circadian rhythms, increases alertness, and enhance performance. Conversely, sleep difficulties and decrements in health and performance have been attributed to a lack of proper use of light.

In FY2011, representatives from the HRP Behavioral Health and Performance (BHP) Element, JSC Space Medicine, and the HRP Space Human Factors

Current fluorescent lighting assemblies (top photo) are scheduled to be replaced with newer Solid-State Lighting Assemblies (bottom photo).

and Habitability (SHFH) Element proposed recommendations for the replacement Solid State Lighting Assemblies (SSLA) on the ISS. The new SSLAs would allow the brightness and wavelengths of the lights to be easily modified depending on the operational need. Such a system would give crewmembers the ability to easily control lighting and use, for example, blue-enriched white light when they need to adapt their circadian clock to another time zone, or conduct critical operations during the night.

The recommended strategy for replacing the lighting assemblies was to outfit all of ISS Node 2 – including the individual crew sleep quarters – first, and then to replace the lights via attrition. The strategy was also driven by the need to use the new SSLA lights to provide increased illumination for performing mission tasks; to minimize crew time used for changing lights; and to be used in future research studies assessing countermeasure effectiveness and lighting protocols. The plan was approved by the ISS Program Board.

BHP, along with SHFH and NSBRI, continues to solicit proposals for research that will define and validate individualized regimens for using light as a countermeasure while minimizing requirements for human system resources.

Crew Prefers "Glenn Harness" for ISS Treadmill Exercise After Successful Test

The weight-bearing exercise afforded by treadmill running on the ISS is crucial for effective gravitational loading of the musculoskeletal system and thus for bone health in space. The current ISS treadmill harness caused discomfort in crewmembers, including chafing, bruising, and scarring at pressure points on the shoulders and hips, and is thought to be a major contributor to sub-optimal mass loading on the treadmill.

A new harness, provided by Glenn Research Center and named the "Glenn Harness," brought an innovative solution to this challenge and was evaluated in an ISS Station Development Test Objective (SDTO) sponsored by the Exercise Countermeasures Project.

An Expedition 29 crewmember exercises with the Glenn Harness on the ISS Treadmill 2 (T2).

After testing was complete, the positive results and favorable feedback from the crew prompted NASA to provide a Glenn Harness for every crewmember who requested one as a "crew preference item."

Lunar Dust Permissible Exposure Limit Set

Potential plans for a return to the lunar surface entail exposure of mission crews to lunar dust. Risks caused by lunar dust exposure were identified during the Apollo missions, when dust was introduced into the lunar lander and command module, resulting in direct exposure and occasional reports of respiratory, dermal, and ocular irritation.

In FY2011, the Advanced Environmental Health (AEH) Project delivered its first installment of a permissible exposure limit (PEL) for the allowable inhalation of lunar dust during spaceflight missions. This interim PEL provides a point from which vehicle designers can project the requirements of future air handling systems of lunar spacecraft and habitats.

An update to this interim PEL is expected, as key tests are in progress to refine the data. Among these tests is an inhalation study being performed by the JSC Toxicology Laboratory that will determine the inhalation toxicity of lunar dust relative to the known standards of quartz – which is very toxic – and titanium dioxide, a non-toxic nuisance dust.

Apollo 17 Astronaut Harrison Schmitt's space suit covered with lunar dust. Apollo crews were exposed to lunar dust that was carried into their vehicles on their suits.

At study completion in 2012, researchers will have established a final PEL for lunar dust inhalation and developed the testing methodology for future destinations, such as asteroids and Mars.

Agency Approves and Baselines the Space Flight Human-System Standard

In FY2011, **Space Flight Human-System Standard (SFHSS), Volume 2, Human Factors, Habitability and Environmental Health, (NASA-STD-3001)** was set as the baseline version of a controlled NASA document. This document, along with **SHFSS Volume 1, Crew Health** and the **Human Integration Design Handbook (HIDH)** replaces the **Man-Systems Integration Standards (NASA-STD-3000)**.

The baselining of NASA-STD-3001, Volume 2 and the HIDH was a multi-year effort that required several document iterations to be developed and a coordinated contribution and collaboration of subject matter experts from across NASA. For decades, NASA-STD-3000 was a significant contribution to human spaceflight programs and to human-systems integration. However, with research program and project results being realized, advances in technology, and the availability of new information in a variety

NASA standards specify clearances for traffic paths. Stowage issues on the ISS make it difficult to maintain these paths.

of topic areas, the time had come to update this set of requirements and design information.

NASA-STD-3001, Volume 2 contains the Agency-level requirements from the human and environmental factors disciplines that ensure that human spaceflight operations are performed safely, efficiently, and effectively. NASA-STD-3001, Volume 2 is applicable to all future spaceflight programs and includes both specific and general requirements.

The HIDH serves as the companion document to, and is intended to aid in the interpretation of, NASA-STD-3001, Volume 2. It contains human-system integration data and lessons learned from previous spaceflight programs making it a compendium of human spaceflight history and knowledge. The HIDH also provides guidance for requirement writers and vehicle and habitat designers.

NASA-STD-3001, Volumes 1 and 2, and the HIDH are publicly available and can be found at the following link: http://www.nasa.gov/centers/johnson/slsd/about/divisions/hefd/standards.

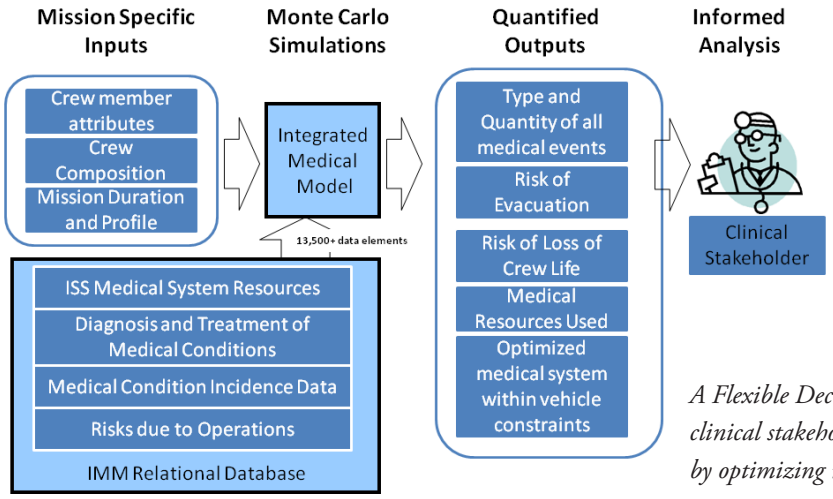
Integrated Medical Model Software Estimates Impact of Events on Crew Health

The Integrated Medical Model (IMM) software tool captures and uses organizational knowledge to forecast potential risks to crew health and mission success. The IMM also helps close the communication gap between the medical and engineering communities and uses current evidence-based information to establish a defensible position for making decisions that help ensure crew health and mission success.

The process of building the IMM adheres to probability risk assessment techniques. The software models not only the likelihood of a risk, but also the available mitigation strategies and the subsequent clinical outcomes that would result from those mitigations. Once the mathematical relationships are established, the IMM uses statistical sampling to determine the probable outcomes. Because the IMM input parameters are represented by various statistical distributions – when a "mission" is simulated with a given set of medical capabilities – a prediction of the most probable outcomes can be generated.

For each mission, the IMM tracks which conditions occurred and decrements the pharmaceuticals and supplies required for treatment. If supplies are depleted, the medical condition goes untreated, and the risks to crew and mission success increase. IMM was delivered with 83 medical conditions integrated into the model, 47 of which have occurred during both short- and long-duration space missions.

Since its transition to operations in FY2011, several NASA organizations have used IMM's modeling capability to assess risk to crew health and mission success based on various mission parameters. In later stages of development, representations of 100 to 120 medical conditions may be achieved.



A Flexible Decision Support Tool - The IMM helps clinical stakeholders mitigate in-flight crew health risks by optimizing mission-specific medical capabilities.

Overview

The International Space Station Medical Project (ISSMP) provides a bridge between flight research and medical operations by planning, integrating, and implementing human research studies requiring access to the ISS, Shuttle, Soyuz, Progress, or other spaceflight vehicles. This support spans pre- and post-flight ground activities and in-flight science operations, and also includes access to on-orbit assets including sustaining engineering of the Human Research Facility (HRF).

During FY2011, ISSMP coordinated and optimized the research supporting three shuttle missions and ISS Increments 26-29. The scope of this work included the launch and return of supplies and samples on each shuttle flight; launch of supplies on five Russian flights, the Japanese H-2 Transfer Vehicle and the European Space Agency (ESA) Automated Transfer Vehicle; and return of ambient samples on three Russian return flights. The loss of the 44Progress vehicle did not affect HRP research on ISS, as those supplies were assigned to future operations and have been re-planned for future flights.

Three investigations completed all in-flight operations and nine studies continued in-flight operations. Also in FY2011, two new investigations began initial flight operations, three new investigations initiated development of flight products to support future missions, and one investigation completed feasibility assessments and is awaiting a future select-for-flight decision.

In addition to supporting the HRP-sponsored research listed, ISSMP provides overall coordination of pre- and postflight testing for ISS and shuttle crewmembers participating in human life sciences research sponsored by other NASA Programs and International Partner agencies. ISSMP also provides support to many of these studies through use of HRF equipment on the ISS.

The ISSMP works with the Space Medicine Division of JSC's Space Life Sciences Directorate, other Program Elements, and International Partners to return the data needed to address key human risk areas. The ISSMP also coordinates with the Space Station Payloads Office to streamline the processes for station use, to increase the research output, and to maximize the number of sets of data that can be returned to guide future research to meet the objectives of the risk reduction program.

To learn more about ISSMP, please visit the public website: http://www.nasa.gov/exploration/human research/elements/research_info_element-issmp.html.

The following table provides a list of all ISSMP active flight experiments, the number of subjects they require, progress in FY2011, and status to date.

Current International Space Station Medical Project Flight Investigations

Investigation Title	Ops Title	Subjects		Status
		Required	Participation Through Increment 29	
Investigations Continuing Flight Operations in Fiscal Year 2011				
Nutritional Status Assessment	Nutrition	30	25	Subject number increased from 24 to 30 in FY2011. After STS-135, this study must await return of frozen samples on SpaceX vehicles to continue data analysis.
Validation of Procedures for Monitoring Crewmember Immune Function	Integrated Immune	17 Shuttle 17 ISS	18 Shuttle 16 ISS	Shuttle phase of study was completed prior to FY2011; remaining ISS subjects have been recruited and study is planned for completion in FY2012.
Bisphosphonates as a Countermeasure to Space Flight Induced Bone Loss	Bisphos-phonates	10 (5 Alendronate and 5 Zoledronic Acid); 10 controls	7 (Alendronate)	Final subjects participated in Alendronate phase during Increment 28-29; subjects for Zoledronic Acid administration are no longer being pursued. Approval given to add a control group to the study in FY2011 targeting data collection beginning with Inc. 31/32.
NASA Biological Specimen Repository	Repository	All	23	Recruitment continues for all future ISS missions. After STS-135, this study must await return of frozen samples on SpaceX vehicles.
Cardiac Atrophy and Diastolic Dysfunction During and After Long Duration Spaceflight: Functional Consequences for Orthostatic Intolerance, Exercise Capacity, and Risk of Cardiac Arrhythmias	Integrated Cardio-vascular	12	6	In-flight operations continued throughout ISS missions in 2011 and are planned to continue in 2012.
Maximal Oxygen Uptake During Long Duration International Space Station Missions	VO2max	12	10	In-flight operations continued throughout ISS missions in 2011 and are planned to continue in 2012.

Investigation Title	Ops Title	Subjects		Status
		Required	Participation Through Increment 29	
Physiological Factors Contributing to Changes in Post-Flight Functional Performance	FTT	13 Shuttle 13 ISS	7 Shuttle 4 ISS	This pre- and post-flight investigation successfully completed data collection for short duration shuttle subjects and is continuing data collection with long duration ISS crewmembers.
Dietary Intake Can Predict and Protect Against Changes in Bone Metabolism During Spaceflight and Recovery	Pro K	16	5	After STS-135, this study must await return of frozen samples on SpaceX vehicles to continue data analysis.
Psychomotor Vigilance Self Test on ISS	Reaction Self Test	24	12	In-flight operations continued throughout ISS missions in 2011 and are planned to continue in 2012.
Investigations with Initial Flight Operations in Fiscal Year 2011				
An Integrated Resistance and Aerobic Training Study for the Validation of an Exercise Countermeasures Regimens Aboard the International Space Station	Sprint	40	1	Flight operations began during Increment 28/29
Biomechanical Analysis of Treadmill Exercise on the International Space Station	Treadmill Kinematics	6	3	Flight operations began during Increment 27/28
Investigations Completing In-Flight Operations in Fiscal Year 2011				
Evaluation of Commercial Compression Garments to Prevent Post-Spaceflight Orthostatic Intolerance	ACG	8 Shuttle	7 Shuttle	Began testing in 2010 with shuttle crewmembers, and completed data collection with the last shuttle mission.
Sleep-Wake Actigraphy and Light Exposure During Spaceflight	Sleep	All Shuttle 20 ISS	80 Shuttle 21 ISS	Study completed long duration subjects during Inc. 25/26, and completed short duration subjects with the last shuttle flight. Transition of this study to medical operations is in progress.
Spinal Elongation and its Effects on Seated Height in a Microgravity Environment	Spinal Elongation	23	19 Shuttle 8 ISS	Successfully completed flight operations during the STS-134 mission.

Investigation Title	Ops Title	Subjects: Required	Subjects: Participation Through Increment 29	Status
Investigations Initiating Flight Development Activities in Fiscal Year 2011				
Behavioral Issues Associated with Long Duration Space Expeditions: Review and Analysis of Astronaut Journals	Journals	10	0	Study is targeting start of flight data collection during Inc. 29/30. Study was previously conducted when ISS crew size was 3 and 10 additional subjects are being pursued now that ISS crew size has increased to 6.
Assessment of Operator Proficiency following Long-Duration Spaceflight	Manual Control	8	0	Study is targeting start of flight data collection during Increments 33/34.
Risk of Intervertebral Disc Damage After Prolonged Spaceflight	IVD	12	0	Study is targeting start of flight data collection during Increments 33/34.
Investigations Awaiting Select for Flight Decision				
Defining the relationship Between Biomarkers of Oxidative and Inflammatory Stress and the Risk for Atherosclerosis in Astronauts during and After Long-duration Spaceflight	TBD	12	0	Feasibility assessment completed in late fiscal year 2011, awaiting select for flight decision.

Final Space Shuttle Flight

In 2011, the Space Shuttle Program was officially retired. Although the end of shuttle flights marked the conclusion of scientific research on missions with a short flight duration, the influence of the Space Shuttle Program will be felt for years. The shuttle provided an extraordinary capability that allowed scientists from across the United States and around the world to gather medical and research data.

ISSMP supported all shuttle science requirements through the end of the program. Research included studies of the neurological and cardiovascular systems, microbiology, the development of engineering

The daytime launch of Space Shuttle Atlantis marked the final mission for the shuttle fleet. The mission, STS-135, delivered vital supplies and equipment to the ISS.

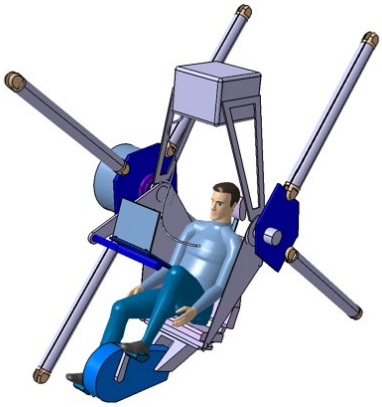
requirements for exploration-class vehicles, and assessment of crew performance.

Although baseline data collection has concluded at the shuttle launch and landing facilities, ISSMP will continue to support the advancement of space research at both JSC and ISS international partners' facilities. The countless lessons learned and advancements in medical and scientific information gained during these shuttle flights enabled the development of the International Space Station and the capability to extend human presence in space.

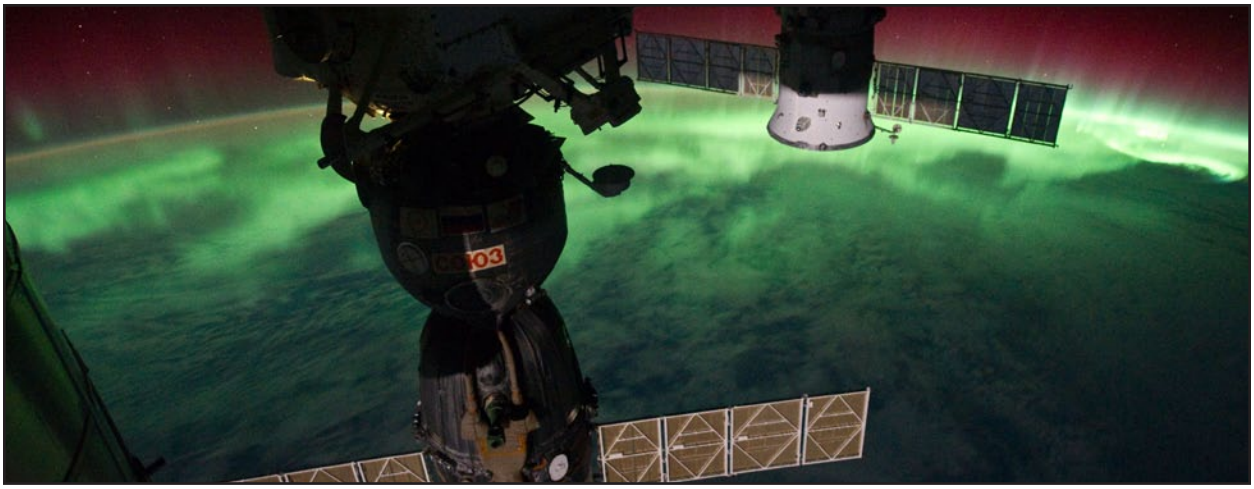
ISSMP Assists with Feasibility Study of Short-Radius Centrifuge

ISSMP personnel provided technical support to an international effort led by the European Space Agency (ESA) and the Japanese Space Agency (JAXA) to investigate the feasibility of implementing a human-powered, Short-Radius Centrifuge system on ISS. This system, called "Artificial Gravity with Ergometric Exercise," would be used as the countermeasure to space deconditioning in humans.

Project reviews during FY2011 concluded that the human-powered element could not be supported – instead, a motor that could maintain a constant rotational speed would be required. ISSMP contributions included completing a feasibility assessment to determine the impact of the centrifuge on ISS Guidance, Navigation and Control as it relates to maximum allowable angular momentum, and completing a loads and dynamics initial assessment and sensitivity analysis. ISSMP personnel also completed an Environmental Control and Life Support System initial assessment for integration into the Permanent Multipurpose Module, which focused on humidity, carbon dioxide concentration, and temperature effects. These technical assessments have provided valuable data and information to the ESA and JAXA team as they consider implementation options.



ISSMP personnel helped investigate the feasibility of a human powered Short Radius Centrifuge system on ISS, called "Artificial Gravity with Ergometric Exercise," as the countermeasure for space deconditioning in humans.



Overview

The goal of the Space Radiation Element (SR) is to ensure that crewmembers can safely live and work in space without exceeding acceptable radiation health risks. Space radiation differs from radiation encountered on Earth.

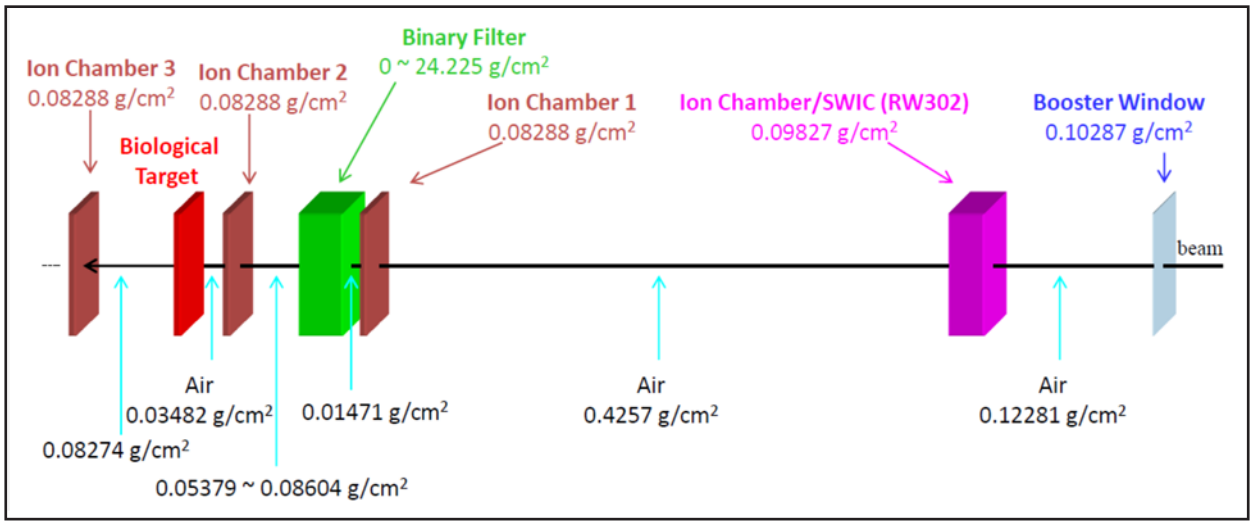
The main sources of space radiation are galactic cosmic rays (GCRs), which consist of protons and electrons trapped in Earth's magnetic field and solar particle events. GCRs permeate interplanetary space and include particles with high ionizing energy. At the cellular and tissue levels, these heavy ions cause damage that is largely different from the damage caused by terrestrial radiation such as x-rays or gamma-rays because of their significantly higher ionizing power and associated uncertainties in quantifying biological response. Shielding against GCRs is much more difficult than shielding against terrestrial radiation because a greater mass of shielding material is required and GCRs can penetrate shielding material.

Health risks from space radiation may include an increased incidence of cancer; acute radiation sickness; degenerative tissue damage; diseases such as heart disease, cataracts, and radiation sickness; and early and late central nervous system (CNS) damage. Cancer risks pose the largest challenge for exploration. The uncertainties in cancer risk projection have large impacts on exploration mission designs, limiting NASA's ability to adjust mitigation measures such as shielding and biological countermeasures. For the CNS and degenerative risks, there are uncertainties in the dose thresholds and latency. Research is needed to optimize radiation protection practices in shielding and operational procedures to prevent acute radiation sickness.

The results of space radiation studies contribute to human exploration by providing a scientific basis to accurately project and mitigate health risks from space radiation. Research in radiobiology and physics guides and supports risk assessment and protection strategies. The results will provide tools for evaluating shielding recommendations for habitats and vehicles as well as requirements for storm shelters and early warning systems for solar particle events. To read more about the Space Radiation Element, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-srpe.html.

Release of Space Radiation Codes

HRP announced the release of the space radiation transport code HZETRN2010 in December 2010. HZETRN (High charge [Z] and Energy TRaNsport) calculates the primary and secondary radiation environment in the body after the interaction of galactic cosmic rays and solar protons with spacecraft materials and human tissue. HZETRN2010 improves earlier versions with a simplified user



The GERMcode model of NSRL beam line supports the analysis of individual primary and secondary particles through biological targets. A beam of particles enters from left, passes through various ion chambers, and filters prior to reaching the specimen.

interface, faster and more accurate calculations, and an enhanced capability to evaluate complex materials and multi-material set-ups. The new version also includes an improved nuclear fragmentation model and forward-backward neutron transport in multi-layer slab geometries. Through a formal software user agreement, the source code is available to U.S. persons who have a contract, grant, or some other form of agreement with NASA or another government agency and who have a legitimate need for the code.

Additionally, two new time-dependent stochastic models of radiation transport and track structure were developed and released as graphical user interfaces (GUIs). These new GUIs, the Galactic Cosmic Rays Event-based Risk Model code (GERMcode) and the Relativistic Ion Track Structure Code (RITracks) were beta-tested by the NASA Space Radiation Summer School students, with the students using the beta-test as their summer school projects.

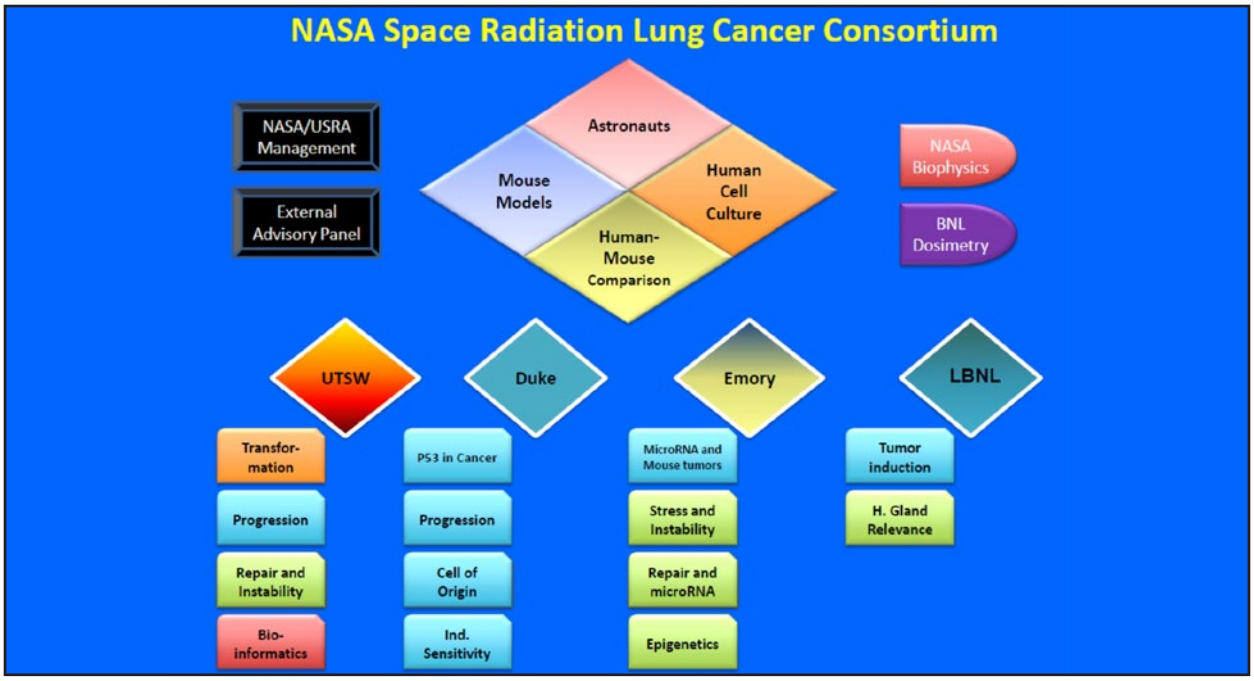
The GERMCode was developed to treat the passage of individual particles through spacecraft materials and tissue in support of new approaches to risk assessment. The GERMcode also contains models of energy deposition in DNA, cell damage and mutation, and mouse tumor induction.

The Relativistic Ion Track Structure Code (RITracks) calculates ionization and oxidative damage from space radiation in biological materials. RITracks includes models of human chromosomes for the entire genome, allowing the user to score the position of DNA damage in whole cells.

New Collaborative Lung Cancer Research

The Space Radiation Program Element formed a Lung Cancer Consortium through the selection of peer-reviewed research proposals, with NASA overseeing integrated planning, research goals, beam testing, sharing of irradiated samples, and the publication schedule of research findings. The consortium of research teams maximizes the strengths of the teams in an integrated effort that will reduce uncertainties in projecting space radiation-induced lung cancer risks. Collaborative efforts are focused on the integrated planning of human and animal cell studies, transgenic animal studies, and bioinformatics and statistics.

Additional collaboration for lung cancer research is being pursued between SR and the National Institutes of Health National Cancer Institute (NCI). In June of 2011, the jointly sponsored workshop "From Mice and Men to Earth and Space: Joint NASA-



This graphic illustrates the NASA Space Radiation Lung Cancer Consortium teams as well as the research focus at each location. The studies occurring at each institution utilize various specimen types such as mouse models and human cell cultures.

NCI Workshop on Lung Cancer Risk Resulting from Space and Terrestrial Radiation" was held at the NCI. Nearly 30 workshop attendees discussed the risk of lung cancer arising after exposure to HZE particle, proton, and low-dose Earth radiation.

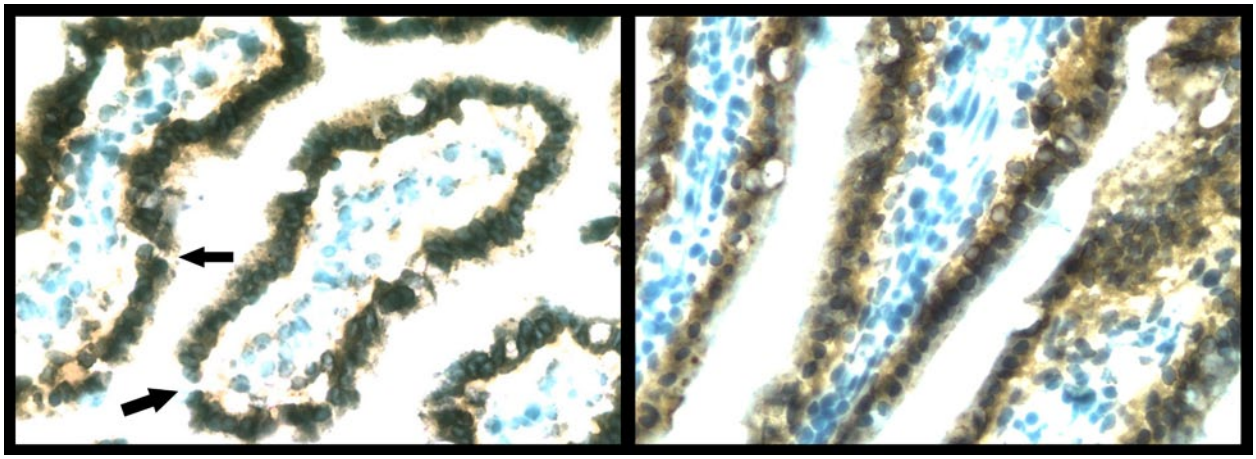
The meeting was prompted by a major issue confronting each organization. For NASA, available data suggest that lung cancer is the largest potential cancer risk from exposure to HZE nuclei and protons during space travel for both men and women. NCI is trying to estimate the increased lung cancer risk from x-rays during the predicted widespread use of computed tomography screening and follow-up for lung cancer in persons at high risk – such as current and former smokers – as suggested by the recent results of the National Lung Cancer Screening Trial.

The focus of the workshop was to evaluate human and mouse models for lung cancer research; describe the diagnostic and therapeutic radiation exposures and the space radiation environment; and explore potential synergies between the two agencies. Also discussed was the effect of smoking history on lung cancer risk and the possibility that the risk for space radiation-induced cancers may be lower for astronauts who have never smoked. A meeting report was published in the journal *Cancer Research*.

Radiation Effects on Intestinal Integrity Studied by the Center for Acute Radiation

Radiation exposure can lead to many health problems, including acute effects such as nausea, vomiting, fatigue, skin injury, and changes in white blood cell counts and the immune system. The NSBRI Center for Acute Radiation Research (CARR) is focused on understanding and mitigating the risks related to acute exposures to radiation. CARR is a central component of the NSBRI Radiation Effects team and has multiple projects assessing the effects of exposure to solar particle events (SPE), quantifying the related risks, and developing and testing countermeasures to prevent and treat symptoms of acute radiation syndrome.

In FY2011, CARR initiated research that involved immunohistochemistry studies of small intestine



Left image: *stained sample of ileum, or small intestine, from a mouse exposed to low-dose proton radiation. Black arrows indicate breaks in the epithelial barrier.* ***Right image:*** *sample from a control mouse. Photographed at 400x.*

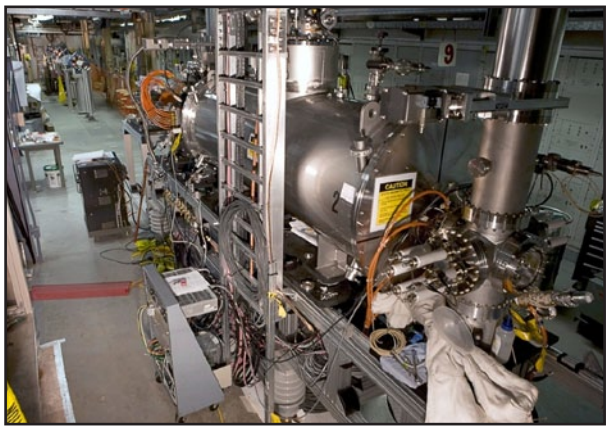
sections from irradiated and control mice. The small intestine was stained for Claudin-3, which is a protein component of tight junctions between epithelial cells of the gastrointestinal (GI) tract. SPE proton radiation caused breaks in the GI tract epithelial barrier. Breaks in this barrier result in a loss of containment of bacteria in the GI tract and the entry of bacteria and bacterial products into the bloodstream. An increased frequency of breaks in the epithelial barrier is thought to be responsible for the appearance of bacterial products in the blood.

New Electron Beam Ionization Source Increases Research Flexibility at the NSRL

Ground-based research in radiobiology is conducted for NASA at the NSRL using beams of high-energy heavy ions to simulate a typical space radiation environment and solar particle events. As a direct result of a long and fruitful relationship between the Department of Energy and NASA, in FY2011 a new Electron Beam Ionization Source (EBIS) was commissioned and is now fully supporting NSRL runs.

The EBIS replaced the Tandem Van de Graaff accelerator, which was previously used as the pre-injector for the Relativistic Heavy Ion Collider and the NSRL. The EBIS consists of a state-of-the-art electron beam ion source, followed by a radiofrequency quadrupole accelerator and an interdigital-H linear accelerator. It can provide any stable ion species from deuterons to uranium, including noble gases such as helium and argon, with much-reduced operating costs and greater operational flexibility. EBIS is capable of switching quickly between different species of ions, so NSRL researchers will be able to integrate multiple ions into a single simulation, rather than waiting for another element to become available.

In FY2011, NASA principal investigators participated in three campaigns at the NSRL that provided the research necessary to support the development of accurate models of radiation-associated health risks and identification of countermeasures to mitigate



A new ion source called 'EBIS' allows NSRL researchers more flexibility in their radiation studies by providing the capability to quickly switch between different types of ions.

those risks. During these campaigns, more than 100 experiments to irradiate a variety of biological specimens, tissues, and cells – with a total of about 1,300 hours of beam time – yielded valuable experimental data. The research results were published in numerous scientific publications such as *Radiation Research*, *Nature Reviews Cancer*, and *The Lancet Oncology*.

Space Radiation Investigators' Workshop

The 22nd Annual NASA Space Radiation Research Investigators' Workshop was held September 2011, in Houston, Texas, and was attended by nearly 200 people. The workshop featured more than 90 oral presentations, 56 posters presented by investigators, and 23 posters presented by postdoctoral researchers, graduate students, and undergraduates in the Student Poster Competition.

Presentations described research results across all radiation risk areas, including radiation carcinogenesis, acute and latent central nervous system effects, degenerative tissue risks, and acute radiation syndromes. Additional sessions included the areas of space physics, technology, and radiation environments, and special refresher lectures on systems biology, stem cell biology, and genomics.

Postdoctoral students, pictured here with guest speaker and Element Scientist, were awarded for their presentations.

Overview

NASA uses the term "countermeasures" to describe the procedures, medications, devices, and other strategies that help keep astronauts healthy and productive during space travel and return to Earth. The Human Health and Countermeasures (HHC) Element is responsible for understanding the normal physiologic effects of spaceflight and developing countermeasures to those with detrimental effects on human health and performance. Before they are tested during flight, candidate countermeasures and technologies are developed and refined using ground-based studies and flight analog environments. An analog is a concept or situation that in some way resembles a different situation. Example analog environments include head-down-tilt bed rest, undersea habitats, and Antarctic outposts.

The HHC is comprised of five projects that address exercise and non-exercise countermeasures, as well as providing flight analog facilities and computational modeling to help test and integrate potential countermeasures before flight verification. Major FY2011 accomplishments are reported in each projects' respective section: Visual Impairment/Intracranial Pressure, Exercise Countermeasures, Non-Exercise Physiological Countermeasures, Digital Astronaut, and Flight Analogs. To learn more, please visit: www.nasa.gov/exploration/humanresearch/elements/research_info_element-hhc.html.

✦ VISION IMPAIRMENT/INTRACRANIAL PRESSURE

NASA recently identified an emerging health risk to crewmembers after observing changes in their vision and ocular anatomy after long-term spaceflight. It is hypothesized that this visual performance degradation is caused by the cephalad fluid shift, or "puffy face," associated with microgravity. Some of the changes in eye structure are papilledema, globe flattening, choroidal folds, "cotton wool" spots, thickening of the optic nerve, and some loss of near visual acuity.

To learn more about this new risk and to determine how to mitigate the effects, NASA initiated a collaborative effort, engaging multiple stakeholders. The result of one aspect of this effort is that a new research project was formed within HHC: the Research Visual Impairment/Intracranial Pressure Project (rVIIP). rVIIP is tasked with defining the underlying mechanisms related to this new risk and implementing a plan to lessen its impact.

rVIIP Summit Held to Address New Risk

A 3-day summit was held in February 2011 with a diverse group of medical and research experts in the areas of cardiology, physiology, ophthalmology, and neurology, the primary systems believed to be involved with microgravity-induced visual impairment and intracranial pressure. The panel recommended

Optic disk edema, or swelling of the eye, is one of several changes observed in 10 out of 35, long-duration crewmembers and is thought to be caused by fluid shifting due to microgravity.

specific diagnostic measures to characterize in-flight physiological changes, hypothesized underlying causes, and suggested tactics for future research. The initial research plan for rVIIP was developed on the basis of these recommendations. The summit report is available at http://humanresearchroadmap.nasa.gov/Risks/?i=105.

rVIIP also contributed topics to the 2011 Human Research Program (HRP) NASA/NSBRI Research Announcement released in August 2011 and expects to fund selected awards from that research solicitation in mid-2012. In the interim, rVIIP initiated directed studies to accomplish short-term goals of the project. The first of these – a data mining activity that analyzes existing ground and flight data for trends and contributing factors – has a completion target in early 2012.

EXERCISE COUNTERMEASURES PROJECT

The Exercise Countermeasures Project (ECP) is responsible for developing effective, efficient exercise protocols and hardware to maintain astronaut health and fitness during long-duration space missions and to preserve the capability to perform mission-critical tasks, both in transit to another planetary body and while on the planetary surface. The ECP conducts ground, spaceflight analog, and flight studies to address risks and knowledge gaps. Additionally, the ECP sponsors research that will guide the Human Spaceflight Medical Standards that relate to muscle and cardiovascular health.

Sprint Experiment Initiated on ISS

The Sprint study enrolled its first participants in 2011 and brings together more than a decade of NASA-funded exercise research to test a newly designed exercise prescription. Sprint combines aerobic exercise, such as treadmill running and cycling, with strength training in new ways. The program consists

The Sprint study involves high-intensity exercise–like sprinting–made possible by new hardware such as the Treadmill 2.

of high-intensity aerobic sprint intervals and a resistance training program intended to better protect cardiovascular, skeletal muscle, and bone health.

New in-flight fitness assessments of maximal aerobic capacity and the careful monitoring of training loads and muscle size allow, for the first time, personal customization of the exercise program during spaceflight. This study would not be possible without the advanced capabilities of the next-generation exercise hardware, the Advanced Resistive Exercise Device (ARED) and the Treadmill 2 (T2). ARED allows users to lift heavy weights and T2 allows the fast running speeds required for sprinting.

Sprint is also noteworthy in its close collaboration between the research and operations communities, which establishes a new model for operational research. The in-flight exercise was jointly developed by NASA exercise physiology scientists in partnership with university subject matter experts and is then implemented by astronaut trainers.

Participants have extensive fitness testing before and after flight for the objective, motivation-independent assessment of muscle function. The tests include assessment of maximal aerobic capacity and ventilatory threshold, ultrasound imaging of the heart, magnetic resonance imaging of the skeletal muscle, a number of muscle function tests, and a muscle biopsy. Participants also receive a Dual-emission X-ray Absorptiometry (DXA) and Quantitative Computed Tomography (qCT) scan for bone monitoring.

70-Day Exercise Bed Rest Study Begins

The Exercise Countermeasures Project (ECP) began a 70-day exercise countermeasure bed rest study with the goal of completely maintaining participants' physical fitness even during long-duration bed rest. Throughout the study, researchers will determine the efficacy of the countermeasures for cardiovascular, muscle, and bone health.

The experimental exercise program used during the study includes four supine resistance exercises – squat, heel raise, hamstring curl, and leg press – three days per week. Aerobic exercise, including a novel interval-training session, is performed six days per week using a customized cycle ergometer or treadmill built for a subject to use while reclining.

Because of the complexity of the 70-day study, ECP initially sponsored a 14-day feasibility study in which participants performed two or three weeks of ambulatory pre-training followed by two weeks of strict bed rest. The exercise program was successfully implemented, well tolerated, and effective in maintaining aerobic fitness, as well as muscle size and function, over the 14-day bed rest period. Additionally, techniques were developed for the use of panoramic ultrasound imaging to assess leg muscle size during bed rest.

Supine exercise equipment allows the subject to remain reclined throughout the exercise session and avoid breaking the strict bed rest protocol. From left to right, the treadmill, squat device, and cycle used by test subjects.

Shortly after the successful completion of the feasibility study, participants were recruited into the longer, 70-day version of the exercise program. The 70-day study's pre- and post-bed rest measurements are closely aligned with that of two ECP flight studies, Sprint and the Functional Task Test. This alignment provides much-needed control data with which to compare flight study results and optimize exercise prescriptions.

Functional Task Test Data Collection Completed for Shuttle Participants

With the landing of STS-135, the Functional Task Test (FTT) project completed data collection on seven shuttle crewmembers. The overall goals of the FTT are to determine the effects of space flight on functions that are representative of high-priority exploration mission tasks and to identify the key underlying physiological factors that contribute to decrements in performance. Microgravity exposure causes adaptations in multiple physiological systems, including the musculoskeletal, cardiovascular, and sensorimotor systems. These changes may affect a crewmember's ability to perform critical tasks immediately after landing on a planetary surface.

FTT uses an interdisciplinary testing protocol that evaluates both astronaut functional performance and related physiological changes. Functions tested include ladder climbing, hatch opening, manual manipulation of objects and tool use, seat egress and obstacle avoidance, and recovery from a fall. Physiological measures include assessments of postural and gait control, visual acuity, fine motor control, orthostatic intolerance, and upper- and lower-body muscle before and after shuttle and ISS missions. Data is collected in sessions before flight, upon landing, and at 1-, 6-, and 30-day intervals after landing.

Forward work includes data collection and analysis of long-duration ISS crewmembers. The information obtained from this study will be used to design countermeasures that specifically target the physiological systems most responsible for the altered functional performance associated with space flight.

Prototype Integrates Endurance and Resistance Exercise into Single Device

Crewmembers spend a great deal of time completing both aerobic exercise and strength training using a variety of devices to counteract the effects of microgravity. NSBRI conducted research with two primary goals: minimize crew time spent on exercise and determine whether a single device could replace the multiple pieces of hardware currently in use.

An FTT test subject performs the hatch opening and a lower body muscle test while instrumented with test hardware.

NSBRI studied a new hardware concept which has the potential to replace multiple exercise devices.

A single exercise device, the Multiple-Mode Exercise Device (M-MED), was used during the study for both aerobic and resistive exercise. The M-MED uses a flywheel to provide the exercise load. It is driven by the efforts of the crewmember, thus requiring no external energy source. With a variety of simple attachments, such as the leg curl arm, the M-MED can provide resistive exercise to most muscle groups. When reconfigured by adding a seat, M-MED provides aerobic exercise in the form of rowing – one of the single most effective aerobic exercises.

Subjects followed a shortened protocol of exercising five days a week, doing aerobic training for three days and resistive training for two days. Each session lasted about 30 minutes. After five weeks, both men and women in the study had increased the strength and size of their muscles and their aerobic capacity.

The results of the study indicated the M-MED provided both resistive and aerobic exercise and that relatively brief exercise sessions utilizing the M-MED may have potential in protecting the health of crew during long-duration space missions. As new spacecraft are developed, the compact M-MED concept may be an attractive candidate to provide critical exercise countermeasures for astronauts.

NON-EXERCISE PHYSIOLOGICAL COUNTERMEASURES

The Non-Exercise Physiological Countermeasures Project (NxPCM) addresses cardiovascular, extravehicular activity (EVA), immunological, skeletal bone, nutritional, pharmacological, and neurovestibular – or sensorimotor – physiology in an operationally driven research program. NxPCM seeks to understand, and if possible, mitigate spaceflight human health and performance issues. During FY2011, the project research portfolio contained 27 ongoing flight and ground research studies performed by intramural and extramural investigators across its seven physiological disciplines.

Study Start for Risk of Intervertebral Disc Damage After Prolonged Space Flight

The Intervertebral Disc Damage (IVD) study, a NASA Research Announcement study selected in April 2009, was approved for flight by HRP in June 2011. Astronauts are currently being recruited, with the first subject expected to launch in late 2012.

IVD test subjects will have upright MRI's taken of the lumbar region of the spine before and after flight.

The purpose of the study is to understand what causes spontaneous back pain during spaceflight and disc herniation after return to Earth. Investigators will describe disc structure and look for signs of tissue degradation before and after ISS missions to see if spaceflight might be causing changes that could lead to injury. State-of-the-art imaging technologies will be used to evaluate the lumbar discs of 12 astronauts before and after prolonged space flight.

Midpoint Review of Bisphosphonates Study

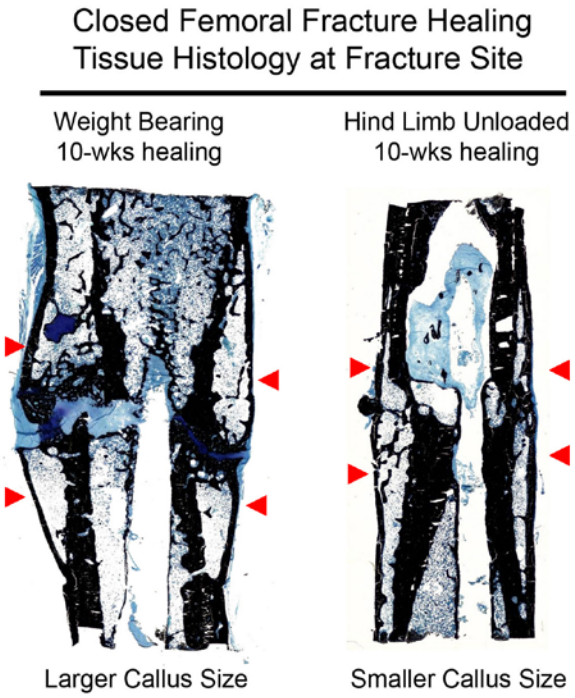
A midpoint data review of the Bisphosphonates Study was conducted in March 2011. The purpose of the study is to determine whether a bisphosphonate – a medication for osteoporosis – when combined with a crewmembers routine in-flight exercise program, will protect against the loss of bone mineral documented on previous ISS flights. The study, a joint project of NASA and the Japanese Aerospace Exploration Agency (JAXA), was selected for flight in January 2007, and the last of seven subjects returned in late 2011.

As part of the review, NxPCM recommended the addition of a set of control subjects who exercise on the same hardware as subjects taking bisphosphonates, to understand the contributions of exercise and pharmaceuticals to the structure and strength of the hip bone. The revised plan was approved by HRP in September 2011 and adds about ten ISS crewmembers who will not take the bisphosphonate medication but will be exercising on an improved hardware design for resistive exercise.

The original study design compared astronauts participating in the bisphosphonate study to previously flown astronauts who did not take bisphosphonates. However, those historical controls did not have access to the improved exercise hardware. Recruiting efforts are now underway for the ten additional control subjects; the first control group is expected to launch in 2012.

NSBRI Study Examines Bone Fracture Healing During Spaceflight

Humans face numerous biological challenges during space flight and not all of them are entirely understood. The accelerated loss of bone tissue experienced by astronauts is well documented and mathematical models show that for these high levels of bone loss, there is a significant increase in fracture risk. Although "fragility fractures" are common in osteoporosis patients here on Earth, they have not been diagnosed in astronauts serving on long-duration missions.



"Skeletal unloading," as in microgravity, alters fracture healing. In this image, the colored areas denote cartilage that are greater in the 'loaded' subject versus the 'unloaded' subject.

The overall goal of the NSBRI-funded research "Extent, Causes, and Countermeasures of Impaired Fracture Healing in Hypogravity" is to identify which long bone fractures have the greatest risk of not healing properly during spaceflight. Additionally, the study will determine why fractures may not heal properly and test the countermeasure efficacy of known treatments.

Previous studies utilized rodents who were either exposed to space flight or "mechanical unloading" to simulate microgravity. These studies indicated that a range of healing responses can occur, from minimal alterations to a healing response that is delayed compared to that of weight-bearing rodents.

The middle stages of fracture healing involving the formation of a cartilage-like tissue were altered and somewhat reduced. Additionally, genes normally

expressed during fracture repair were expressed at lower levels in unloaded rodents than in their weight-bearing counterparts. This information guides the countermeasure development strategies for this study.

Countermeasures Being Developed to Enhance Sensorimotor Adaptation

Astronauts often experience balance problems after returning from space flight. To counteract this phenomenon, NSBRI is developing a training program to help astronauts adapt to different gravity environments and therefore decrease the caloric energy consumed during balance instability.

For the study, NSBRI designed and tested a unique training system composed of a treadmill placed on a hydraulic tilting base. The treadmill faces a virtual scene that provides a variety of balance and sensory challenges. This combination of scenery and motion serves as a training technique to improve the brain's ability to adapt to new environments.

A subject walks on a tilting treadmill while presented with a virtual-reality, moving scene. Exercises like this are thought to improve balance adaptability and could be used as a countermeasure for astronauts returning from space.

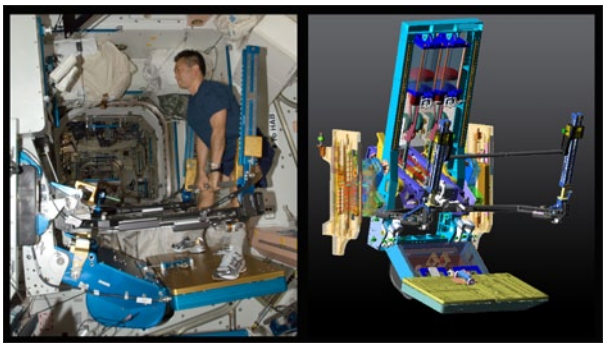
Results indicate that training using a combination of modified visuals and motion of the support surface enhances both walking adaptability and multi-tasking capability. This improved performance can be retained for six months, indicating that a component of this training could take place before long-duration missions. It has also been shown that subjects who rely more on vision for control of their movement have more difficulty adapting their walking strategies in new environments. This result indicates that dependence on vision may be a "marker" for decreased ability to adapt to novel environments. Predictors of adaptability can be identified before flight to develop customized training prescriptions that would make the training process targeted and more efficient.

✦ DIGITAL ASTRONAUT PROJECT

Predicting the effects of space flight on the human body is challenging. Longer, more physically demanding missions necessitate a better understanding of human physiology during space flight to establish health and safety requirements for these new missions. The Digital Astronaut (DA) Project is developing a detailed computer model of the human body. This model will be used to predict the effects of spaceflight on each body system. Researchers have developed detailed models of bone loss, kidney stone formation, and the heart. This model will be useful to the medical community to aid in understanding disease and may lead to improvements in pharmaceuticals, surgical procedures, and treatments.

Digital Astronaut Project Conducts Collaborative Analysis of ISS Hardware

During FY2011, DAP developed an Advanced Resistive Exercise Device (ARED) model in conjunction with exercise simulations developed by JSC exercise physiology and countermeasure personnel.



In response to an on-orbit hardware issue, DAP developed an ARED model (shown on right) to ascertain if the removal of the ARED's flywheels would still yield adequate resistance for effective crewmember exercise.

The ARED is used by ISS crewmembers to preserve muscle strength during long-duration missions. This collaborative effort leverages HRP resources from different projects and centers to facilitate the process and achieve optimal results. This unique collaboration will continue in FY2012 and will result in the characterization of muscle forces generated in microgravity by ARED resistance exercises.

An on-orbit ARED hardware issue led to an early payoff for this work in FY2011. The ARED flywheels were disengaged because of concerns that set screws could back out of their engagement on the flywheel shaft. Given the tight constraints on ISS crew time for repair of the issue, the ISS Program Office requested information on the consequences of operating the ARED without the flywheels, with the understanding that a long-term fix would be implemented at some point in the future.

To meet that request, motion-capture data of subjects performing exercises on the ARED ground unit were collected. These data were used as inverse dynamic input into the ARED model. An analysis was performed with and without the flywheels being engaged. The model, developed with collaborative input, showed that without the flywheels engaged, the force variation was minimal meaning that they could be removed without significant impact to the crew exercise program.

✦ FLIGHT ANALOGS PROJECT

Overview

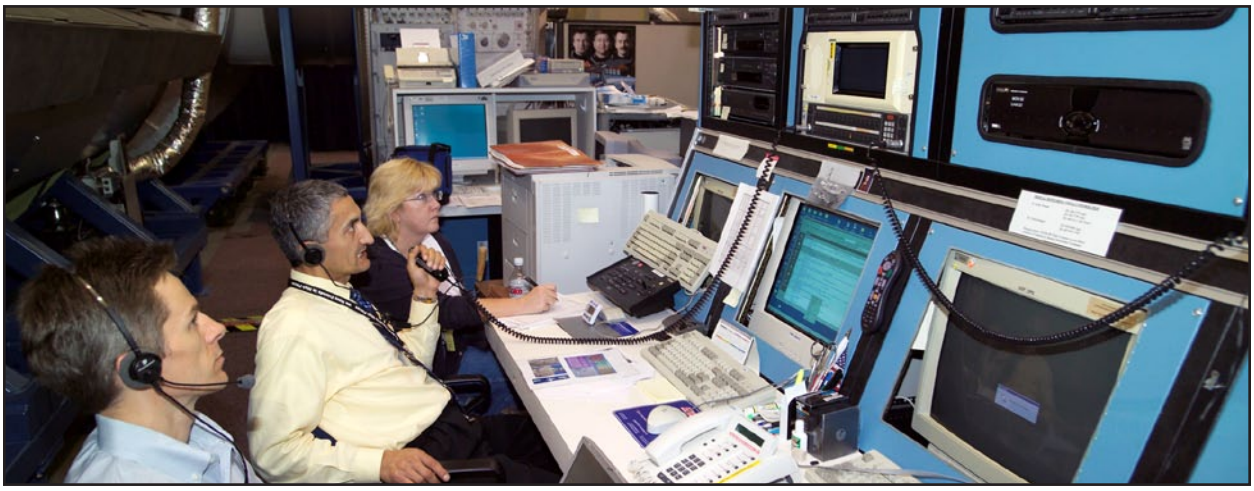
The Flight Analogs Project (FAP) supports a variety of investigations using ground-based analogs to answer research questions that address HRP spaceflight risks. These ground-based analogs include: the NASA Extreme Environment Mission Operations (NEEMO) Aquarius facility in Florida; the Haughton-Mars Project in Devon Island, Canada; research stations in Antarctica; Desert Research and Technology Studies in remote areas of Arizona and California; Human Rated Chamber Complex at Johnson Space Center in Houston, Texas; and the Flight Analog Research Unit (FARU) bed rest facility at the University of Texas Medical Branch in Galveston, Texas. A summary of the characteristics of these analogs that make them ideal for studying spaceflight phenomena on Earth are listed in the following table.

FAP integrates and coordinates HRP's ground analog research studies. As the integrator, FAP reviews study requirements, assesses those requirements

The FAP uses remote locations such as the undersea NEEMO-Aquarius habitat as research 'analogs' to mimic the conditions found in spaceflight and planetary missions.

with respect to analog characteristics, integrates compatible studies into a complement and coordinates with analog owners to utilize analogs that best meet the research requirements. During study implementation, FAP provides oversight to insure successful completion of these research complements.

Analog Characteristics	FARU - UTMB	NEEMO	Devon Island / HMP	Antarctica	Desert RATS	Human Related Chamber Complex
Environment/Terrain External to Habitat						
Desert (may include Arctic desert)			●	●	●	
Island			●			
Ice sheet				●		
Sub-ocean		●				
Other	●					●
Extreme Environment Features						
Hypoxia						●
Hyperbaric						●
Atypical day length			●	●		
High humidity		●				
High temperature					●	
Low temperature			●	●	●	●
Characteristics						
Confinement within habitat	●			●		●
Crew hierarchy (Commander, etc.)		●				
Microgravity simulation (0g)	●	●				
Lunar gravity simulation (1/6g)	●	●				
Mars gravity simulation (3/8g)		●				
Difficult or limited logistics		●	●	●		
Isolation from outside world		●	●	●		●
Limited local infrastructure		●	●		●	
Remote communications			●	●		●
Autonomous operations		●	●	●		●
Autonomous medical care or "telemedicine"		●	●	●		
Moon/Mars-relevant field/EVA activities		●	●		●	
Lunar surface simulation			●		●	
Martian surface simulation			●		●	



Overview

Human exploration of the Moon, Mars and other destinations beyond near-Earth orbit will present significant new challenges to crew health. During exploration missions, the crew will need medical capabilities to diagnose and treat injury or disease. Providing capabilities that overcome these challenges requires new health care systems, procedures, and technologies to ensure the safety and success of exploration missions.

The Exploration Medical Capabilities (ExMC) Element develops medical technologies for in-flight diagnosis and treatment as well as data systems to protect patients' private medical data, aid in the diagnosis of medical conditions, and act as repositories of information about relevant NASA life science experiments.

ExMC physicians and scientists develop models to quantify the probability of medical events occurring during a mission. They also define procedures to treat an ill or injured crewmember without access to an emergency room and with limited communications with ground-based personnel for consultation and diagnostic assistance. To read more about the Exploration Medical Capability Element, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-exmc.html.

Telemedicine Workshop Focuses on Gaps for Near-Earth Asteroid Mission

ExMC hosted a Telemedicine Workshop in January 2011 to solicit expert opinion on current telemedicine practices and on medical care in remote environments. The likelihood of a medical incident is increased on long-duration exploration missions and the availability of medical capabilities and resources to diagnose and treat medical conditions will likely be limited. It is anticipated that a more structured use of telemedicine will become highly desirable.

The workshop brought together leaders in telemedicine and remote medicine from The University of Texas Medical Branch, Henry Ford Hospital, Ontario Telemedicine Network, U.S. Army Institute of Surgical Research, University of Miami, American Telemedicine Association, Doctors Without Borders, and the Pan American Health Organization. The group included engineers, former astronauts, and physicians specializing in surgery, emergency medicine, internal medicine, and aerospace medicine.

The primary objectives of the workshop were to document the medical operations concept for a crewed mission to a near-Earth asteroid, to determine gaps between current capabilities and the capabilities outlined in the operations concept, to identify research required to close these gaps, and to discuss potential collaborations.

Gaps in the following areas were identified before the workshop began: crew medical officers, patient area in spacecraft, training, electronic medical records, intelligent care systems, consultation protocols, prophylactic surgical procedures, and data prioritization. The gaps were discussed in detail during the workshop and a summary of the discussions held and conclusions reached were documented in a final report.

New NASA Human Research Wiki Increases Collaboration with External Partners

In preparation for exploration missions, ExMC compiled a large evidence base of medical conditions that could occur on-orbit. This data was previously available only to persons within the NASA community. In an effort to make this information available to the general public and increase collaboration with subject matter experts within and outside of NASA, ExMC has developed an online collaboration tool, titled the "NASA Human Research Wiki."

The wiki encompasses several types of data, including information on more than 80 medical conditions that could occur during spaceflight. In addition, about 35 gap reports are included that identify current knowledge and any gaps in knowledge or technology that would need to be addressed in order to provide adequate medical support to future exploration missions. These potential conditions are derived from several sources, including the Integrated Medical Model.

The NASA Human Research Wiki will disseminate ExMC medical evidence and increase collaboration opportunities with subject matter experts.

The platform chosen for this data sharing, and the potential collaboration it could generate, was a wiki-based website that houses the evidence, allows read-only access to all visitors to the website, and allows editorial access to credentialed and approved subject matter experts. Although traditional wikis allow users to edit information in real-time, the NASA Human Research Wiki includes a peer-review process to ensure quality and validity of new inputs.

The wiki was launched in September 2011 with a subset of data and will continue to be populated throughout the year. The wiki is also intended to be a demonstration for other HRP Elements that may want to use this type of web-based tool. Visit the wiki here: http://humanresearchwiki.jsc.nasa.gov.

Intravenous Fluid Generation Experiment Analysis of Results and Final Report

The Intravenous (IV) Fluid Generation (IVGEN) project was developed to design and test a system capable of producing United States Pharmacopeia (USP)-grade IV fluid using resources available in orbit. IVGEN was designed to generate IV fluid from potable water produced by the ISS Water Processing Assembly (WPA), using a water purification technique and pharmaceutical mixing system. The hardware was launched to the ISS in April 2010 and on-orbit testing occurred the next month.

The IVGEN experiment utilized a deionizing resin bed to remove contaminants from feedstock water to achieve a purity level that meets the standards of the USP, the governing body for pharmaceuticals in the United States. The water was then introduced into an IV bag, where the fluid was mixed with USP-grade crystalline salt to produce USP Normal Saline.

In FY2011, a final report was compiled and results indicated that all of the success criteria for the ex-

In FY2011, the final results of the IVGEN experiment were generated. In the photo above, an Expedition 23 crewmember poses in front of the Microgravity Science Glovebox after installation of the IVGEN.

periment were met, except for the salt concentration. Problems with a large air bubble in the first bag of purified water resulted in a slightly concentrated saline solution of 117% of the target value of 9 g/L (grams per liter). The second bag had an inadequate amount of salt premeasured into the mixing bag, resulting in a slightly deficient salt concentration of 93.8% of the target value. The USP permits a range from 95 to 105% of the target value.

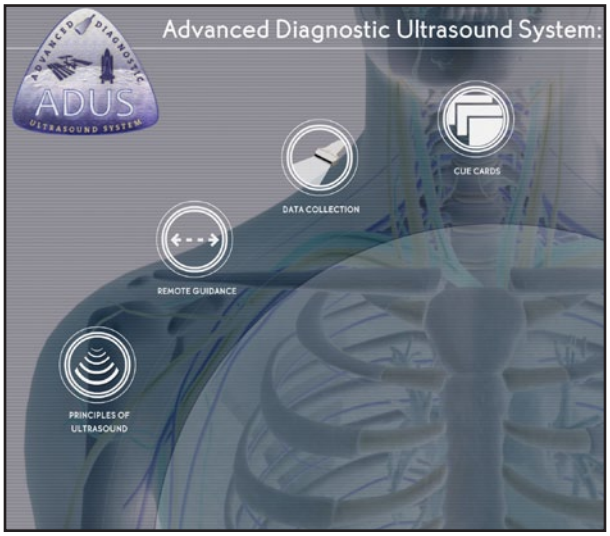
The experiment yielded valuable information for the future development of a fully operational unit. In FY2011, this information was documented in a final report which also detailed plans for improvements. These plans call for the incorporation of an air-water separator to prevent air bubbles from infiltrating into a dry accumulator and a different method to verify the amount of salt crystals preloaded into the mixing bags.

The ISS has an activated carbon filter in its WPA, but future spacecraft may not incorporate this feature; consequently, plans also called for integrating an activated carbon filter into the IV generation hardware to provide additional filtration against complex organic molecules.

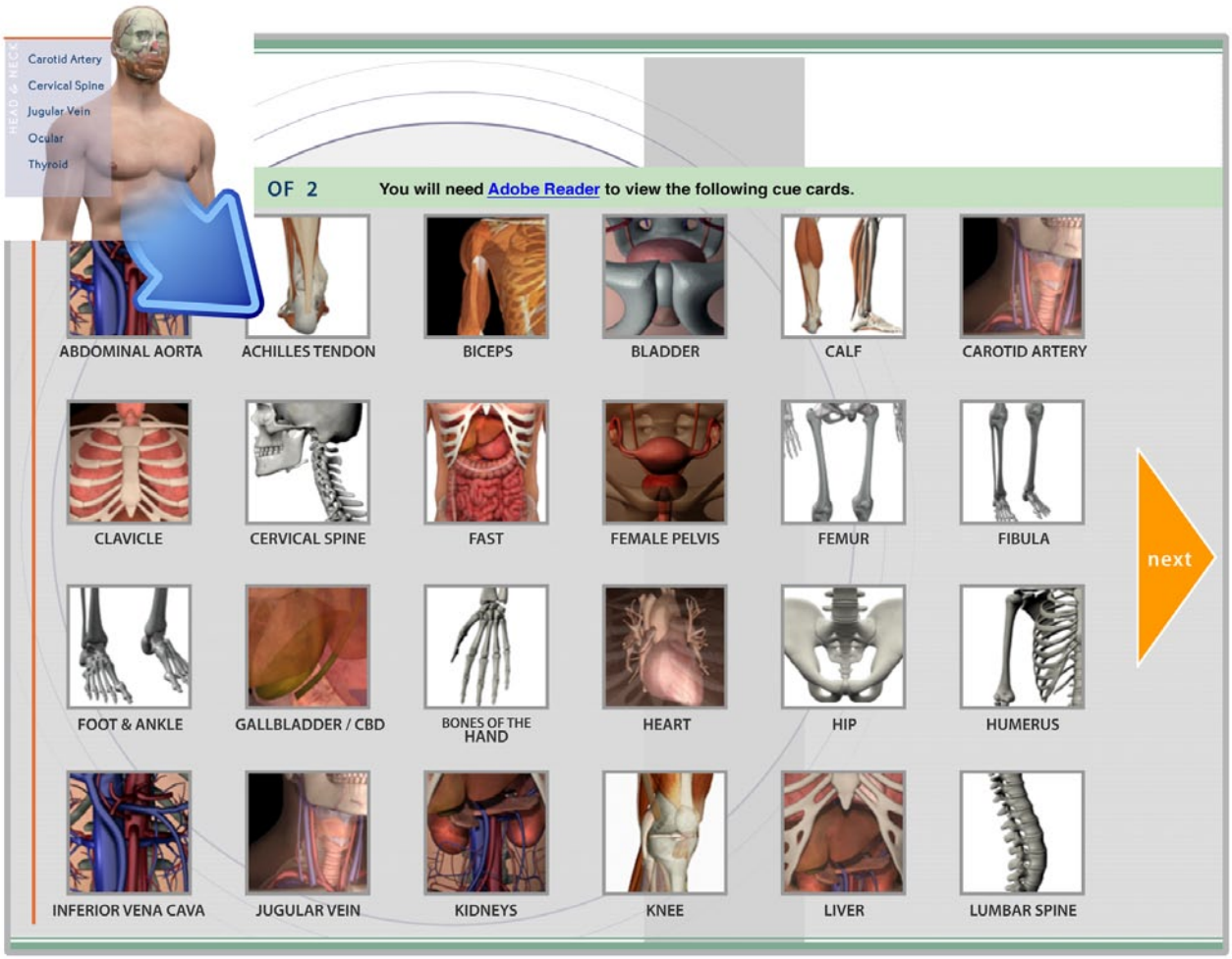
New Diagnostic Guide Developed to Assist in Remote Ultrasound Imaging

The diagnosis and management of acute health problems in space is problematic because of limited training of the crew and limited diagnostic resources. An ultrasound system is operational in the Human Research Facility and could be used to manage a majority of potential medical problems, serving as a powerful tool to mitigate risks and protect the mission. Recent terrestrial investigations suggest that expanded clinical applications of ultrasound could be used to diagnose over 75% of potential in-flight conditions. Currently, remote ultrasound guidance from mission control is used to aid astronauts in acquiring ultrasound images.

The Advanced Diagnostic Ultrasound System (ADUS) Guide was developed by NSBRI as an education tool for astronauts in the acquisition of clinical images. As an alternate to remote guidance, ADUS enhances the capability of the crew to perform ultrasound imaging. It is intended to assist sonographic examinations in which the operator either lacks ultrasound expertise or real-time support.



The ADUS was developed as an educational tool to aid non-medical crewmembers on the use of the ultrasound. The guide is divided into four sections: Principles of Ultrasound, Remote Guidance principle, Data Collection and Cue Cards.



The ADUS uses a 'cue card' concept to guide crewmembers in the proper execution of ultrasound techniques such as placement of the probe prior to scanning, essential keyboard controls, and imagery guides to facilitate pattern recognition.

The multi-media format demonstrates hand and patient positioning and provides image examples in a convenient layout. The intuitive nature of the guide represents an enhancement in remote guidance and aids in autonomous performance of the standardized examinations of patients.

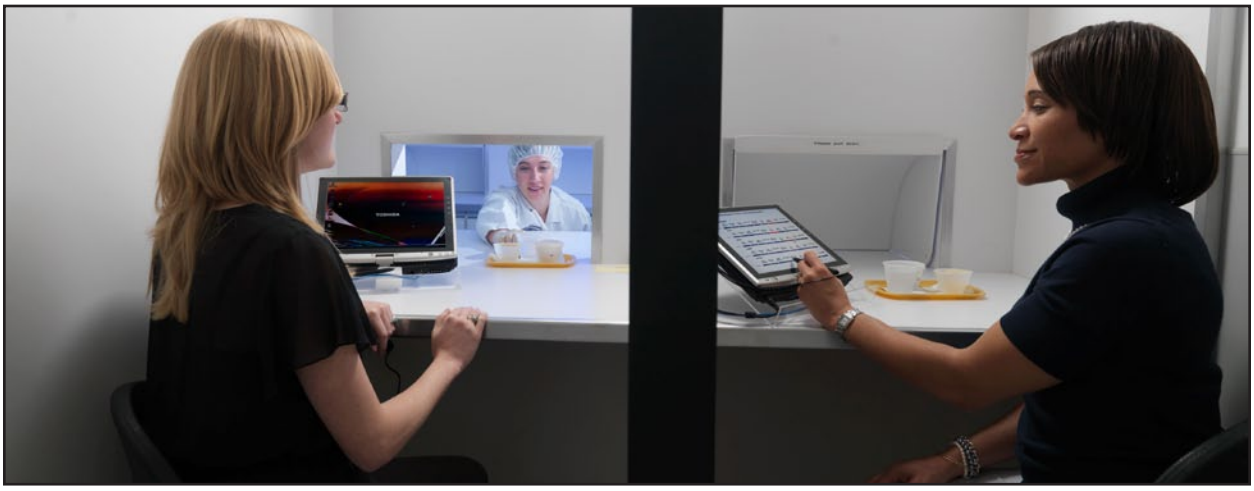
Validation of NIRS Biosensor for Determination of Oxygen Utilization During Exercise

Prolonged bed rest is used to simulate the effects of space flight on the cardiovascular system. One of the most noticeable effects of bed rest is a decrease in aerobic capacity or peak oxygen consumption, also known as VO2pk, which can result from changes in the volume of blood that the heart pumps with each beat and the use of oxygen by skeletal muscle. Near-infrared spectroscopy (NIRS) provides a non-invasive assessment of oxygen utilization in muscle, and could be used to help understand the effects of bed rest on VO2pk.

The study "Validation of Near Infrared Spectroscopy (NIRS) Measures Following Bed Rest" was a collaborative effort between NSBRI and the JSC Cardiovascular Laboratory and Flight Analogs Project. The purpose of the study was to assess the sensitivity of a NIRS biosensor for determining changes in muscle oxygen utilization that accompany changes in exercise responses after bed rest.

A subject wears a NIRS non-invasive biosensor on their thigh for determining oxygen utilization during aerobic exercise.

NSBRI developed a unique biosensor that differentiates the muscle data from the signal of overlying skin and fat. With funds from the U.S. Army, the NIRS biosensor was reduced in size and weight so it would easily fit on the thigh of an astronaut in a spacesuit. For the nine subjects in the long-duration bed rest study, the NIRS biosensor detected an increase in the use of oxygen by the leg muscles during cycling that was similar to the decrease in aerobic capacity at the end of the bed rest period.



Overview

The Space Human Factors and Habitability (SHFH) Element consists of three main project areas: Advanced Environmental Health (AEH), Advanced Food Technology (AFT), and Space Human Factors Engineering (SHFE).

The AEH project focuses on understanding the risk of microbial contamination of the spacecraft and on the development of standards for exposure to potential toxins, such as lunar dust. The project also provides environmental quality requirements for spacecraft and space missions, particularly for the atmosphere and water.

The AFT project focuses on reducing the mass, volume, and waste of the entire integrated food system to be used in exploration missions, while investigating processing methods to extend the shelf life of food items up to five years. The project also delivers improvements in both the food itself and the technologies for storing and preparing it.

The SHFE project establishes human factors standards and guidelines for human-machine interactions to ensure optimal productivity of space crews in both physical and cognitive interactions with hardware and software. SHFE also provides validated models for predicting the effects of interface designs on human performance, methods for measuring human and human-system performance, and improved design concepts for advanced crew interfaces and habitability systems.

To learn more about SHFH, please visit the public website at: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-shfh.html.

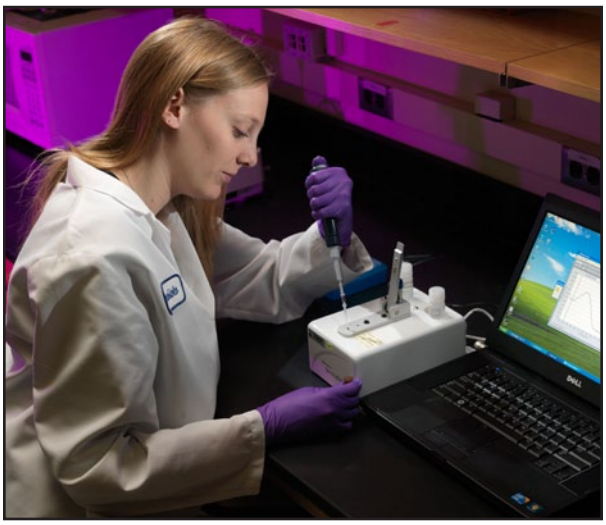
✦ ADVANCED ENVIRONMENTAL HEALTH PROJECT

The AEH project focuses on the definition and investigation of environmental risks that can adversely affect the safety, health, and performance of the crew and on technology and operational activities to mitigate those risks. Specifically, AEH research leads to requirements that influence vehicle design, flight operations, payload design, and food and water quality. Additionally, AEH research incorporates technology investigations that could directly influence those requirements, including environmental monitoring and remediation techniques.

Current AEH tasks include the establishment of permissible exposure limits (PEL) to lunar dust and investigation of requirements for foods with high microbial content–such as probiotics or freshly grown foods. Additionally, AEH investigates new microbiological requirements which prompts the incorporation of new, advanced technologies.

Modeling of Microbial Risk in ISS Potable Water Supply Complete

Although preventive measures limit the presence of many medically significant microorganisms during a spaceflight mission, microbial infection of crewmembers cannot be completely prevented. One potential source of infection is the water supply used by the crew for drinking, food preparation, and hygiene. Any spacecraft water system has the potential to become contaminated, but no studies have ever been performed to quantify the risk of contamination on crew health.



A NASA microbiologist measures the concentration of DNA in an environmental water sample using a Nano Drop Analyzer to enable microbial identification.

To address this lack of knowledge, the AEH project partnered with personnel from the University of Texas Health Science Center at Houston to review ISS water systems and historical monitoring data to evaluate the current potable water systems and assess the risk to the crew. The technique, called "quantitative microbial risk assessment," uses sophisticated mathematical models to determine risks.

The evaluation found that while the risk to the crew was not significantly higher than the risk of drinking water from a drinking well or municipal system, many factors increased the uncertainty. Among these factors are the high potential for: biofilm formation, disruption of the immune system, and changes in microbial virulence. In addition, the reliance of the crew on only one or two water sources also increased the risk that contamination could result in crew illness. This evaluation marks the first study to begin quantifying the microbial risks associated with long-duration spaceflight and establishes a foundation from which to target key factors to mitigate those risks.

✦ ADVANCED FOOD TECHNOLOGY

The AFT project is responsible for providing space crews with a food system that will enable safe, reliable, and productive human space exploration. The food system must be safe, nutritious, and acceptable to the crew, while efficiently balancing appropriate vehicle resources such as mass, volume, waste, and food preparation time for exploration missions. These requirements necessitate the provisioning of a packaged food system with a shelf life of 3 to 5 years. Current ISS food system technologies cannot meet these requirements.

The importance of the food system in a long-duration manned exploration mission should not be underestimated. Food not only provides the nutrients needed for the survival of the astronauts, but also enhances the psychological well-being of the crew by being a familiar element in an unfamiliar and hostile environment.

Packaging Study Identifies High-Barrier Materials to Prolong Food Shelf Life

AFT is currently designing a stable, palatable, and nutritious food supply to support long-duration missions beyond low Earth orbit. Identifying high-barrier food packaging is integral to this work because food quality is greatly reduced upon exposure to environmental moisture and oxygen. The Comparative Packaging Study evaluated the long-term performance of three packaging materials: a low-barrier

Sensory evaluation or 'taste tests' are an important part of food quality testing. Test subjects are presented with a control sample of food and asked to compare it to a sample that has been packaged in each test material.

transparent material, a high-barrier transparent material, and a high-barrier opaque material.

For the study, each of the three test materials was used to package one ingredient and two food products, which are all extremely vulnerable to oxygen and moisture-induced spoilage. The quality of these food items was examined regularly during 36 months of storage at relevant temperature and humidity conditions.

During these examinations, the foods were evaluated for any increases in moisture content and staling aroma compounds, as well as changes in other quality indicators. Taste tests were used to assess the quality of the foods over time by comparing the aging items to control samples.

The assessment of the food items indicated the relative longevity of each of the three packaging materials. The opaque material preserved the food quality the longest–greater than 36 months. Its success appeared to be unaffected by the different storage conditions studied.

After considering all results, AFT researchers were able to establish minimum limits for food quality indicators, which will likely simplify future food storage studies. Furthermore, the results will yield recommendations on the use of these high-barrier materials to ensure the quality of food for storage on current and future missions.

Food Processing vs. Packaged Food Trade Study Underway

For exploration missions beyond low Earth orbit, use of resources across subsystems is a critical determinant in cost, complexity of launch scenarios, and mission infrastructure. A key habitability question for Mars mission planners is whether to send prepackaged food provisions with the crew; to have the crew grow food plants as part of a bioregenerative, closed environmental system; or to use a combination of plants and prepackaged food.

A trade study is underway to compare the three systems and the results will be used to determine the degree to which crop growth and food processing should be used for Mars missions. Four factors are assessed for each of the scenarios: the mass of food required, food preparation time, the sensory acceptability of the menu items, and the mass of the equipment needed for preparation and cooking.

"Spiced caramel coffee cake" was produced by food scientists using only the ingredients and equipment available to the crew as scoped for a bioregenerative food system on Mars.

Initial results indicate that the significantly lower mass of stowed food and high acceptability of the recipes favors the use of a bioregenerative system. However, the extensive time needed to produce the recipes and process intermediate ingredients, such as tofu from soybeans, is a disadvantage. Adding some prepackaged foods to the crop-based foods decreases the active crew time by only 15%. Using exclusively prepackaged foods requires much less crew time. As the total equipment mass was relatively low compared to food masses, its contribution was insignificant in the comparison between the food scenarios.

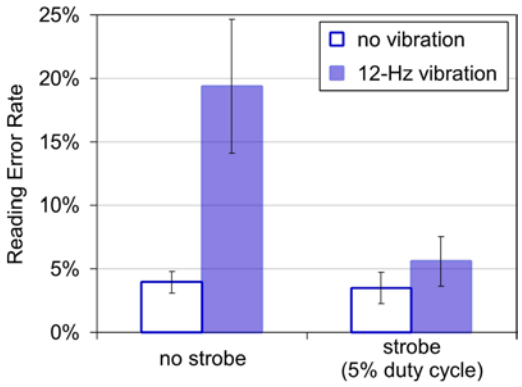
At the conclusion of the study in September of 2012, the four factors will be weighted to provide each scenario with a quantitative score. Also, a feasibility assessment of implementing the scenario with the lowest score will be reported.

SPACE HUMAN FACTORS ENGINEERING

The SHFE project provides critical answers for the design of the next generation of NASA spaceflight systems. To ensure that humans can perform long-duration missions safely and effectively, SHFE scientists and engineers conduct studies in a variety of settings, from the laboratory to analog environments to spaceflight. They also collect the information needed to verify that the crew's work environment, tools, and system interfaces support their tasks. In a variety of domains, the SHFE team works closely with design and space operations experts to ensure appropriate and timely solutions to their human-systems integration issues.

Stroboscopic Countermeasure Improves Visual Performance Under Vibration

Vibration-induced head motion causes visual blur that can hamper the readability of information displays, potentially compromising the ability of astronaut crews to monitor and control their vehicle. A series of previous laboratory and centrifuge studies demonstrated this significant degradation in human visual performance during whole-body vibration representative of a space launch.



Reading error rates for subjects exposed to stroboscopic countermeasure were almost identical to the control group experiencing no vibration. The study's impressive results have led to an application for a U.S. Patent.

Building from these studies, SHFE developed and tested a new stroboscopic countermeasure that visually "freezes" image movement, thereby eliminating the perceived blur of otherwise stationary objects seen by vibrating observers. This countermeasure can be implemented by rapidly strobing a computer display panel and switching it "on" and "off" in synchrony with real-time measurements of the observer's chair vibration pattern.

The efficacy of the stroboscopic countermeasure was demonstrated in a laboratory study of display readability involving 11 subjects under chest-to-spine vibration at the maximum vibration rate permitted by the Constellation Program, as well as under a zero-vibration control condition. For a strobe duty cycle of the display being switched "on" 5% of the time and "off" 95% of the time, the countermeasure reduced reading task error rates to levels statistically indistinguishable from the strobed and non-strobed, non-vibration conditions.

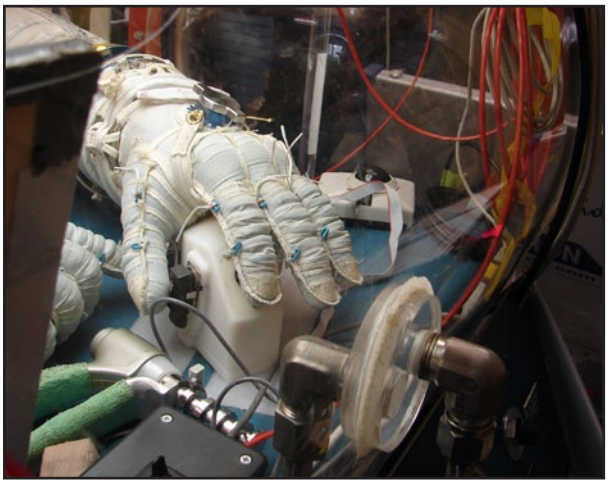
In addition to use with crewed space systems, this technology also may be applicable to information displays in high-vibration environments on board air, ground, and sea vehicles. NASA has filed for a U.S. Patent on this invention.

Study Investigates Effects of High Suit Pressures on Gloved Performance

Future spaceflight missions may include some contingency operations in which suit pressures must be higher than what is currently considered nominal. SHFE researchers, in collaboration with the Extravehicular Activity (EVA) Suit Team at JSC, performed a glovebox study to investigate the strength and mobility of the human hand, and the ability to operate small controls while wearing pressurized gloves. In this feasibility study, performance measures were collected under a range of glove pressures.

Four study participants tested controls including a castle switch, a rocker switch, a trackball, push buttons, edge keys, and a rotary knob – all representative of types of controls being considered for future space vehicle cockpits. The castle switch, rocker switch, and trackball were tested using a software-based, cursor control task.

Results indicated that, with respect to mobility, increased pressure seems to affect thumb mobility more than that of the index and middle fingers. Additionally, grip strength is reduced by approximately 25% by wearing a glove and showed only a 15% further reduction with increasing pressures.



Subjects assessed the operability of various controls such as a rocker switch and trackball inside a pressurized glovebox.

There was a ballooning effect of the glove at higher pressures, which affected participants' ability to grip. With respect to the cursor controls, response times for the castle switch steadily increased with increasing pressure, whereas response times for the rocker switch seemed to be unaffected by increasing glove pressure. Response times for the trackball were most affected by the addition of the glove itself. The greatest number of errors was made with the trackball.

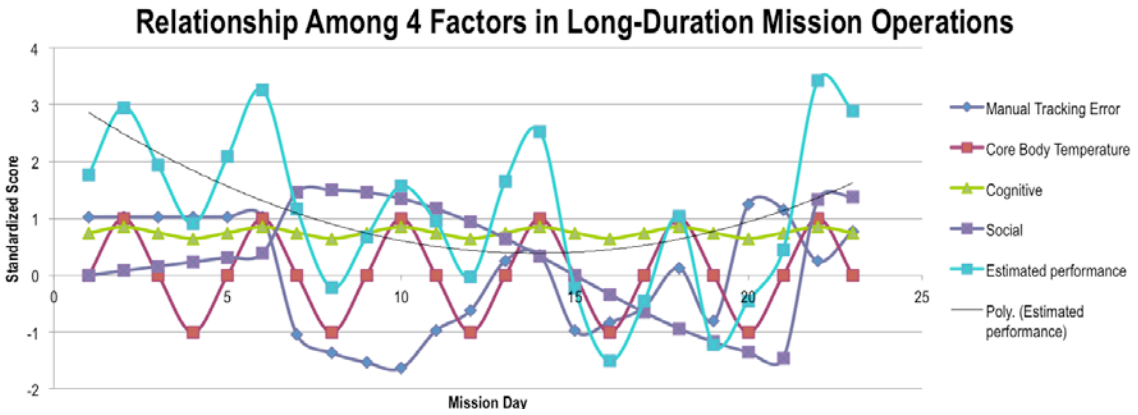
This study is notable in that it is the first known test of the operability of small controls under such high glove pressures. Additional studies are being planned with a larger sample size to evaluate performance with different hand and glove sizes, as well as with alternative device designs that may be more ergonomically flexible and forgiving of changes in hand and finger dimensions.

Unobtrusive Measurement of Workload for Long-Duration Missions

An HRP-funded study conducted research on the requirements for unobtrusive measures of workload and of workload management. A review of three crew debriefs helped identify the likely variables that need to be considered when designing interfaces, procedures, and schedules so that an acceptable workload is maintained throughout a mission.

FY2011 activities included an overview of system, system operations, and system engineering processes. Two conceptual models were developed as they might pertain to long-duration mission operations. It is anticipated that future research will use these models as a starting point to further recommend considerations, and to expand the primary, secondary, and tertiary variables that need to be considered to unobtrusively measure workload throughout long-duration missions.

In FY2011, one new technology was identified to unobtrusively measure workload. Additional technologies have been highlighted in various developmental stages that may provide unobtrusive ways



This graph projects performance over a month-long mission. Core Body Temp captures the circadian rhythm, Cognitive models variations in cognitive performance due to fatigue. Social represents the strength of social cohesion with a 2nd half transition. Estimated Performance sums the values of each factor across time.

to measure workload while providing feedback to astronauts, who can use the information to manage their tasks with the ultimate goal of safety of the entire system to achieve mission success.

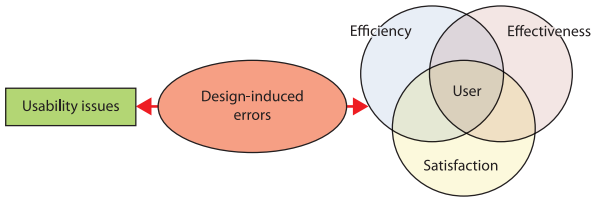
Error Rates Used as Metric in Development of Usability Requirement

A number of standards exist for the operational evaluation of "usability" which recommend evaluation in terms of effectiveness, efficiency, and satisfaction. All three factors are important and are key elements of the human-centered design approach. Applying usability evaluation to system development contributes to crew health and safety. Furthermore, improved usability reduces errors, training time, and overall lifecycle costs, and is essential to ensure crew safety and mission success.

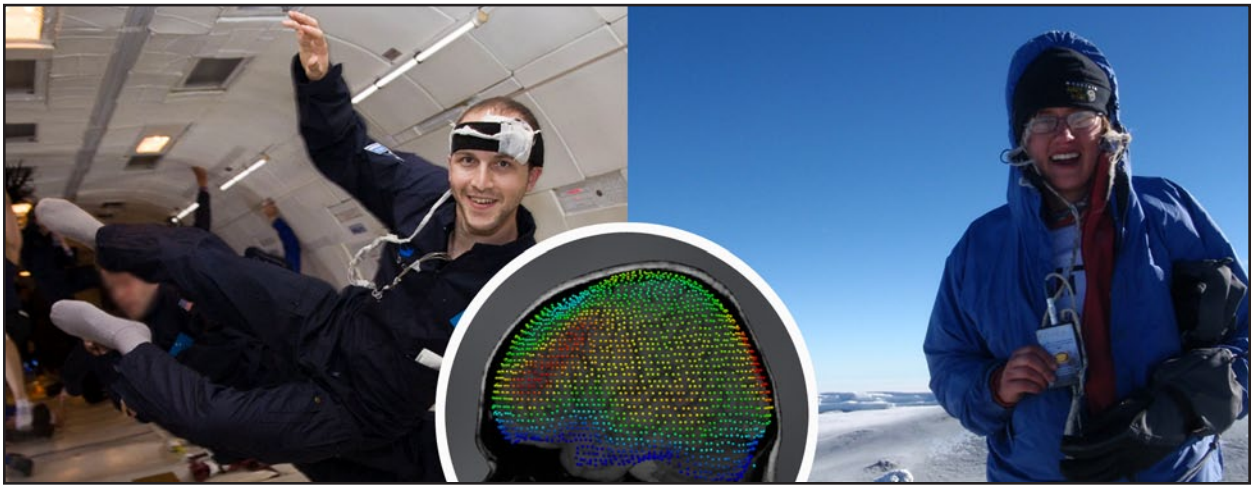
In developing a usability requirement, SHFE researchers focused on error rates as the chosen metric. The metric is objective, easy to understand, and relates to all factors of usability. All spaceflight tasks are driven by formal written procedures, so usability problems were identified by calculating error rates per procedure step and per participant, rather than calculating an overall error rate. Furthermore, the focus was on design-induced errors.

In a usability test it is important to detect steps associated with many errors. Identification of these steps suggests that they have usability issues and can be associated with a design problem with the hardware, software, or instructions. It is equally important to detect participants who commit many errors. The usability requirement takes into account both of these aspects, and thus uses criteria for both based on testing and simulations. As a result, it ensures that the number of design-induced errors is minimized for every task step and every participant.

Achieving a usability requirement in a NASA document is a significant accomplishment because this is a first step toward full inclusion of usability in the development life cycle. NASA is at the forefront of evolving the practice of usability by having a verifiable usability requirement applying objective measures for usability verification.



This graphic shows the relationship among errors, usability issues and the three main factors of usability.



Overview

The Behavioral Health and Performance (BHP) Element conducts and supports research to reduce the risk of behavioral and psychiatric conditions. These include performance decrements due to inadequate cooperation and communication within a team and the risk of errors due to fatigue resulting from sleep loss or work overload.

Long-duration missions, beyond low Earth orbit, will require crews to adapt to increasingly autonomous operations in isolated, confined, and extreme environments. Crews are faced with other challenges such as long periods of heavy workload, separation from home, and altered day-night/light cycles. Microgravity, carbon dioxide, and radiation are other factors that may also lead to debilitating neurobehavioral and performance outcomes.

BHP's strategy for addressing its risk reduction research is derived in a systematic manner and driven by operations. Spaceflight analogs and other research environments are carefully assessed to ensure that the individual, team, environment, and mission characteristics fit the research question at hand.

To address these concerns, BHP categorizes research into three areas: Behavioral Medicine, Team Risk, and Sleep Risks. The Behavioral Medicine Risk area aims to develop self-assessment tools for early detection and treatment that use unobtrusive and objective measures of mood, cognitive function, and other behavioral reactions to living and working in space. The Team Risk area examines team performance and other team-related outcomes, including crew cohesion and communication, to develop tools and technologies that monitor teams throughout autonomous operations. The Sleep Risk area focuses on countermeasure development, including lighting protocols, medication recommendations, education, and tools that optimize work-rest schedules.

The end result is to provide technologies and tools that will optimize the adaptation of the individual and crew to the space environment, and maintain motivation, cohesion, communication, morale, well-being, and productivity.

To read more about the Behavioral Health and Performance Element, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-bhp.html.

Cognitive Assessment Tool Evaluates Long-Duration Crew Performance

A prototype cognitive assessment tool, known as CogGauge, was delivered at the conclusion of a successful Small Business Innovative Research Phase 2 contract. Using mini-games, the tool is aimed at characterizing cognitive function in astronauts on

long-duration missions where high cognitive workload, disturbed sleep conditions, and other physical and mental stressors may be present.

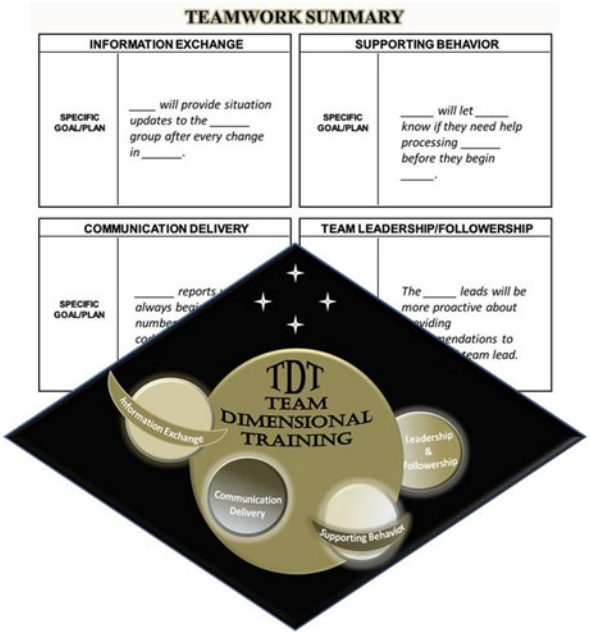
CogGauge is inspired by the Automated Neurophysiological Assessment Metrics (ANAM) family of tasks. A subset of these tasks was adapted into nine mini-games that follow a space exploration theme titled "Solar Hunt." Each game is targeted to assess memory, learning, and perceptual processing at various levels of difficulty. Accuracy, response time, and throughput metrics are captured on each game, and provide a clear indication of potential cognitive deficits that may have an impact on future tasking. The metrics are then analyzed using the CogGauge diagnostic algorithm to determine probable cause for any identified cognitive deficit.

Solar Hunt is a series of nine mini-games to assess memory, learning, and perceptual processing at various levels of difficulty. The tool is aimed at characterizing cognitive function in astronauts on long-duration missions.

Terrestrial users of CogGauge could include long-haul pilots, military personnel, nuclear power plant operators, and individuals subjected to shift work. The Department of Homeland Security and NASA are supporting a 1-year enhancement phase that will allow validation of the tool in populations analogous to NASA astronauts.

Improving Teamwork and Performance Through Self-Correcting Strategies

Efficient and effective team interaction and performance will be essential for successful future long-duration missions. BHP is overseeing Team Dimensional Training (TDT) research which focuses on improving teamwork and team performance and is a strategy for enhancing the ability of teams to self-correct. This type of training is valuable for future missions and has a positive value for current spaceflight operations.



Team Dimensional Training (TDT) is a structured debriefing technique to improve teamwork and team performance.

TDT incorporates a facilitator to help guide team self-correction and to develop members' teamwork-related knowledge and skills. This approach helps groups develop shared, accurate knowledge about the components of teamwork and to accelerate their mastery of targeted teamwork skills through a debriefing strategy following team-related events. This teamwork strategy will be implemented with current mission control teams to validate the strategy for spaceflight missions.

Software Developed for Behavioral Tracking

The Behavioral Tracking Tool is a software tool that enables the collection of behavioral data. This software program may be utilized as a resource for upcoming selection and astronaut activities as well as a feedback and learning tool for flight controllers. This tool will also be of use in preparation for long-duration missions.

The software is flexible in multiple respects. First, the user has the ability to design behavior rating scales and to determine the metrics that will be measured. Thus, the program could be used multiple times for different purposes. Second, the program runs on a number of devices, including smartphones and laptops. The program offers multiple modes to track behaviors, such as an audio recording, video recording, or direct input.

The tool also includes an evaluation component so that users can produce reports and provide real-time feedback to participants. These technologies will improve teamwork and team performance, as efficient and effective team interaction and team performance are essential components of successful missions.

The Behavior Tracking Tool 'app' allows researchers to easily collect, document, and report crew actions and behavior.

Reaction Self Test on ISS

Sleep loss, schedule shifting, and heavy workloads are regular aspects of spaceflight. Evidence from ground-based studies shows that these factors, experienced by those similar to astronauts and in doses similar to those in space, lead to performance decrements. The Psychomotor Vigilance Task (PVT) is widely regarded as a reliable and valid measure of fatigue for both laboratory and operational settings. The PVT detects changes in neurobehavioral performance and has been validated in ground-based studies to detect cognitive deficits caused by a variety of factors, such as restricted sleep, mental workload, and residual sedation from sleep medications.

Meaningful measures that briefly assess cognitive function are needed particularly before performing critical operations.

The inventor of the PVT, through the support of NSBRI, BHP, and the Department of Homeland Security, has developed a 3-minute version of the test that also includes a feedback interface. This test, known as the "Reaction Self Test," was developed so that the PVT could serve as both a data collection measure and an operationally relevant tool, offering astronauts a quick way to assess their own performance acuity before they perform critical tasks.

The purpose of this investigation is to validate the Reaction Self Test as a measure of fatigue-related cognitive performance during spaceflight. In 2009, the PVT was implemented in flight and data acquisition began with Expedition 21-22. To date, nine

astronauts have completed the in-flight phase of the experiment. Baseline data collection is underway or has been completed on 15 astronauts. In-flight data acquisition is underway or has been completed on 12 astronauts, with a total of 864 Reaction Self Tests performed in flight or an 85% adherence rate.

SMART-OP Software Provides a Stress Management Countermeasure

Training for and executing a long-duration mission poses many stress-inducing challenges such as time away from family, communication delays, and isolation and confinement. An NSBRI study has developed an evidence-based, self-guided, software which trains users to manage stress and build resilience. The program, called Stress Management and Resilience Training for Optimal Performance (SMART-OP), includes education about stress and interactive training exercises that teach users to regulate physiology, think flexibly and realistically, and take effective action to deal with stressors. The content of the program can be modified to target different populations and could be disseminated widely to computers or smartphone devices.

SMART-OP was recently evaluated in a randomized trial with a sample of 66 stressed, but otherwise healthy, UCLA Law and Business School students. SMART-OP users were compared to a control group who received self-guided stress management training that included watching commercially available videos and reading published information on the topic.

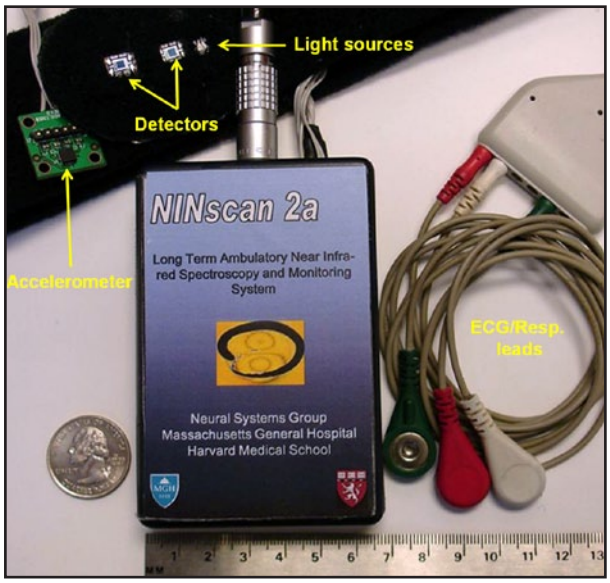
Initial analyses show that SMART-OP significantly reduced perceived stress, increased perceived control over stress, and was rated as more useful and acceptable than the tools used by the control group. These results suggest that SMART-OP can be an effective stress management countermeasure that could be used autonomously.

Objective Detection, Evaluation, and Countermeasures for In-flight Depression

Spacefarers encounter numerous physical and psychological stresses arising from sources such as space radiation exposure, microgravity-induced fluid shifts, elevated carbon dioxide levels, prolonged confinement, vigilance required to monitor a dangerous external environment, and the threat of potential serious physical injury. On Earth, each of these sources of stress has been shown to alter brain function.

Prefrontal brain regions that govern planning, problem solving, and flexible thinking seem particularly vulnerable and are also affected by neuropsychiatric conditions such as depression. Unfortunately, typical Earth-based neuroimaging methods—including PET, MRI, and CT—are too heavy to operate on orbit. As a result, a method for assessing cerebral functioning is not currently available on the ISS.

NSBRI investigators have been developing wearable technologies to monitor blood perfusion and



The latest prototype of the near-infrared neuroimaging (NIN) sensor weighs less than 600 grams and fits in a pocket.

Researchers have developed wearable devices for monitoring brain oxygen which were tested in extreme environments, including parabolic flight and an ascent of Mt. Kilimanjaro.

oxygenation of the brain, known as near-infrared neuroimaging (NIN). Three prototypes have been developed, each weighing less than 600 grams, including devices that integrate NIN with heart- and body-movement sensors for a more comprehensive physiological evaluation. The most recent NIN design could be used to develop a whole-head imaging system on a pocket-size recording device.

Testing is ongoing, including evaluations of NIN device sensitivity to brain activity in prefrontal cortical regions, and usability of the device in operational analogs of spaceflight. A parabolic flight test demonstrated the system's sensitivity to cerebral blood volume changes associated with gravitational variations. Three separate ascents up Mt. Kilimanjaro in Tanzania have demonstrated the system's usability by non-experts and robustness to extreme environmental conditions.

The Kilimanjaro expeditions have also provided preliminary evidence of altered cerebral function in individuals experiencing acute mountain sickness (AMS). This finding may be particularly relevant to spaceflight, since AMS is a condition of concern in NASA's Integrated Medical Model, and is thought to be related to mild cerebral edema and hypertension, similar to the recently reported phenomenon of spaceflight-induced intracranial hypertension.

Overview

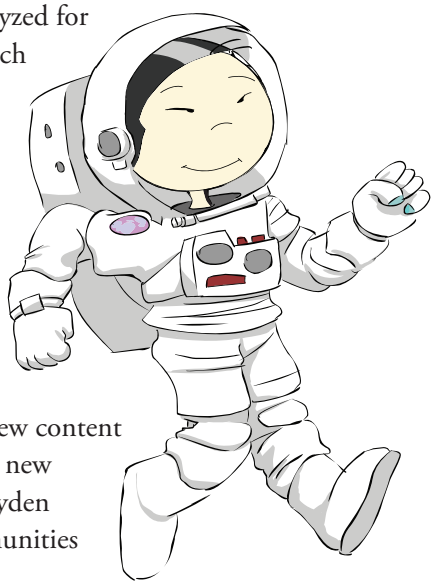
The Human Research Program Education and Outreach (HRPEO) Project is committed to using NASA's expertise in space research and exploration to educate the nation in science, technology, engineering, and mathematics (STEM). Project activities and materials target educational communities, the general public, policymakers, and the media using formal and informal venues. The HRPEO Project made significant progress in strengthening their K–12 programs and outreach efforts during the past year. Their primary-grade programs include the 21st Century Explorer and Fit Explorer initiatives. Secondary programs include Math and Science @ Work, and Exploring Space through Math. To learn more about HRPEO please visit: www.nasa.gov/exploration/humanresearch/education.

Primary Education Initiatives

During FY2011, HRPEO experienced significant growth in the design, development, and assessment of its primary education projects. HRPEO expanded its Fit Explorer content with the advent of the first international fitness challenge, Mission X: Train Like an Astronaut (TLA).

Eleven countries assisted with and participated in this pilot event. Fit Explorer, through the Train Like an Astronaut USA national challenge, had the opportunity to begin a new partnership with the White House's Let's Move Initiative (LMI). The new partnership was approved by the White House and NASA Headquarters in August 2011. TLA materials were distributed across more than 600 U.S. cities involved in the LMI. Fourteen new training videos were developed for TLA, and were accompanied by a newly enhanced website that was released in September 2011. The videos will be released in FY2012.

In FY2011, the HRPEO team finished compiling data derived from the 21st Century Explorer (21C) summer camp research study attended by Girl Scouts from Iowa and Illinois. The 21C project consists of hands-on educational content for formal and informal venues in English and Spanish. Project data is being compiled and analyzed for the second implementation which was held in Southern Arizona during the summer of 2011. The evaluation will be used to improve future content to help advance students' knowledge and skills in science, technology, engineering, and mathematics.



The HRPEO team finalized a new content product for 21C and initiated a new partnership with the NASA-Dryden Office of Education and Communities

in California. The project was top rated on a new educational rubric, or scoring tool, for NASA Headquarter's Office of Education during Summer 2011.

Secondary Education Initiatives

HRPEO secondary math and science projects, Exploring Space Through Mathematics (ESTM) and Math and Science at Work (MS@W), marked an increase in the release of new educational content in FY2011 with the assistance of Texas Instruments (TI). TI partnered with HRPEO to review new educational content which lead to a significantly shortened turnaround time.

Facebook pages were created for ESTM and MS@W and used in a NASA Math and Science week with TI. As part of this, two live UStream broadcasts with NASA subject matter experts were created. TI also used MS@W material during their national summer teacher training, "Connecting Math and Science" and "High School Science" workshops. HRPEO staff and TI representatives developed two electronic professional development (ePDs) modules with NASA Explorer Schools (NES).

HRPEO content was used by the NES in two additional ePDs prepared by NES staff. MS@W expanded content to include activities for advanced placement Statistics classes. A new website was created for ESTM in December 2010, and ESTM expanded content to include activities for algebra-2 and pre-calculus.

8TH Annual Space Radiation Summer School

The Space Radiation Element, in support of developing the next generation of radiobiology researchers interested in space, selected 17 students to attend the 8th annual NASA Space Radiation Summer School held at Brookhaven National Laboratory in June 2011. Participants included domestic and foreign graduate students, postdoctoral fellows, and faculty in biology and physics.

The 8th annual NASA Space Radiation Summer School participants stand outside the NSRL at Brookhaven in Long Island, New York.

The integrated curriculum of radiation biology, radiation chemistry, and physics culminated in hands-on accelerator-based experiments. Forty faculty members from leading universities and national laboratory biologists and physicists, who are actively engaged in NASA space radiation research, lectured on their areas of expertise. The Director for the 2011 and 2012 Space Radiation Summer School is a retiree from the United Kingdom (UK) Medical Research Council.

NSBRI Postdoctoral Fellowship Program

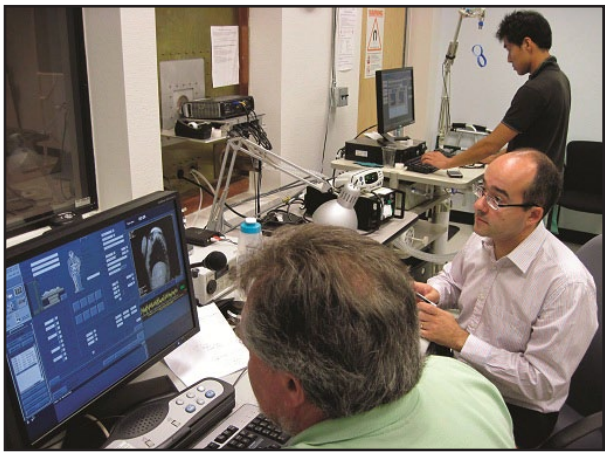
Established in 2004, the National Space Biomedical Research Institute (NSBRI) Postdoctoral Fellowship program funds academically talented young scientists to conduct research that will result in the delivery of countermeasures to ensure the health of astronauts during spaceflight, and to apply findings from this research to benefit human health on Earth.

The program has shown success in training independent investigators. Over their careers, the 25 NSBRI-sponsored postdoctoral fellows representing 20 US graduate programs and 11 states have produced 312 peer-reviewed articles (130 as first author), nine book chapters, three books as editor, 656 abstracts, and seven invention disclosures. Fellows have conducted research in the NSBRI areas of cardiovascular alterations, human factors and perfor-

mance, musculoskeletal alterations, radiation effects, sensorimotor adaptation, and smart medical systems and technology.

Of the 17 fellows who have completed the 2-year award, two have received funding for a competitive third-year NSBRI postdoctoral fellowship, ten have obtained faculty appointments, two have accepted non-NSBRI postdoctoral fellowships, and two have accepted industrial positions. Fellows completing the program are now located in Japan, Germany, and the United States.

In addition to conducting research, fellows are required to attend NSBRI's Bioastronautics Institute in Houston. This academic program further equips fellows as they transition to the role of independent investigator. Offerings include mentoring strategies, presentation skills, ethics, grant writing, and information about community outreach opportunities. NASA and NSBRI representatives also provide overviews of their programs in research and education.



NSBRI research fellows (foreground) study a subject's breathing patterns using MRI while a graduate student (background) monitors the subject's vital signs.

Summer Research Program and Minority Research Internships

The Summer Research Program is a collaboration between NSBRI and the Morehouse School of Medicine (MSM), a historically black medical school. The program offers summer laboratory research internships to further the preparation of students from population groups traditionally underrepresented in STEM and encourages them to pursue STEM-related higher education and careers. By providing intensive research experiences at MSM and Harvard Medical School for motivated undergraduate, medical, and graduate students, the progam is strengthening the pipeline of women and underrepresented students entering medicine and biomedical research careers in the U.S.

Students work in a laboratory at the Morehouse School of Medicine (MSM) as part of an NSBRI-funded internship.

Since 1997, the Summer Research Program has enrolled 70 students through NSBRI sponsorship. The demographics of participants show 61 African-American, seven Caucasian, and two Asian participants, of which 39 were women and 31 were men.

Space Life Sciences Summer Institute

The Space Life Sciences Summer Institute (SLSSI), held in the summer of 2011, engaged student interns through seminars, lectures, and tours to educate them on the current biomedical issues associated with human spaceflight and space exploration. SLSSI, in its seventh year, continues to creatively introduce the paradigms, problems, and technologies of modern spaceflight within the framework of the JSC Space Life Sciences Directorate (SLSD).

This year's Institute included one of the most diverse groups of students, with interns representing 18 U.S. states and France. Although the Institute is managed and operated at JSC, student interns from Glenn and Ames Research Centers also participated through webcasts.

Undergraduate, graduate, and medical students from various majors and disciplines from 33 top colleges and universities worked alongside NASA scientists, physicians, and engineers to play an intricate part in individual projects and ongoing research. These future scientists and engineers were affiliated with 26 laboratories within SLSD and contributed to many varied projects, from Acoustic and Noise Control to Space Radiation and Analysis.

SLSSI was able to incorporate feedback collected from prior institutes to make improvements. This year the Institute improved communications and provided more interactive seminars, such as the SLSD Peer Panel. These improvements led to the highest student participation to date. SLSSI also brought back the highly popular hands-on demonstration of the Space Shuttle Advanced Crew Escape Suit and lectures and tours of the Neutral Buoyancy Laboratory pool, Mission Control Center, and space vehicle training mockups.

Students in the SLSSI participated in lectures and hands-on demonstrations such as the Space Shuttle Advanced Crew Escape Suit session.

HRP Strengthens Collaborative Relationships with Research Communities

The HRP will continue to strengthen collaborative relationships with the ISS International Partners through various working groups, integration of research efforts in ground analogs, and increased ISS research collaboration and data sharing. The National Space Biomedical Research Institute (NSBRI) will utilize the new Consolidated Research Facility (CRF) to collaborate through product demonstrations and interactions with Rice University and other specialists located within Houston's prestigious Texas Medical Center.

The scientific community continues to be an integral partner in addressing human health and performance risks. HRP plans to release at least two NASA Research Announcements (NRA) in FY2012, and participate in the Small Business Innovation Research (SBIR) solicitation. Additional solicitations will be considered as necessary. The following workshops will also be held in FY2012: the annual HRP Investigators' Workshop in February, the Space Radiation Investigator's Workshop in July, and the Behavioral Health and Performance Workshop in August.

Mission X Evolves into an Annual Event

The HRP Education and Outreach project, Mission X: Train Like an Astronaut (TLA), will proceed with international challenges through FY2014. Mission X 2012 anticipates participation by at least 18 countries with materials available for use in 11 languages. The USA team is expected to involve more than 3,000 students who will participate in the challenge. Plans are also in work for Mission X to participate in a pre-Olympic 2012 venue in London, England.

In its new partnership with the White House's Let's Move Initiative (LMI), TLA will continue to distribute materials to schools across the nation. Also, as part of the program's expansion, 14 Mission X activities will be supplemented by instructional videos that underscore the importance of physical fitness and nutrition and how they relate to astronaut health during spaceflight and on Earth.

ISS Medical Project Looks Forward to Demonstration of Commercial Resupply

The commercially developed SpaceX "Dragon" spacecraft is planned to complete its initial demonstration flight in 2012. Once the capability of the module has been fully demonstrated, HRP will regain the capability to return biological samples and equipment back to Earth for analysis. Sample return is a key requirement for HRP and is essential in addressing the human health risks associated with long duration microgravity exposure. ISSMP will continue supporting the eleven investigations that were in implementation in 2011 as well as begin

Once operational, the SpaceX "Dragon" craft will re-establish the capability for sample and equipment return from orbit.

data collection with crewmembers for three experiments: Journals, Manual Control and Intervertebral Disk Damage. In addition, seven new investigations are expected to begin flight development activities in FY2012. New investigations include: oxidative and inflammatory stress for risk of atherosclerosis; new standard measures for visual acuity and intracranial pressure; ultrasound imaging of inter-vertebral discs; study of the impact of long-term space travel on the astronaut's microbiome; spaceflight effects on neurocognitive performance; occupational risk surveillance for bone; and effects of long-term exposure to microgravity on salivary markers of innate immunity.

NAS to Complete the Validation of the Space Radiation Risk Projection Model

The report from the National Academy of Sciences (NAS) will be delivered to NASA in the spring of 2012. NASA will review their recommendations and update the Space Radiation Risk Projection model as appropriate. The resulting Graphical User Interface (GUI) will be made available to NASA personnel, ISS partners, and interested scientists and mission designers. The HZETRN2010 code (High charge [Z] and Energy TRaNsport) will be updated to include improved light ion and neutron transport models. An updated version of the Design Tool for Vehicle Radiation Shielding Assessments and an updated version of the Acute Radiation Risk and BRYNTRN (BaRYoN TRaNsport) Organ Dose model will be released in 2012.

HHC Element Validates and Begins Full Implementation of rVIIP Research Plan

The Research and Clinical Advisory Panel (RCAP) will meet for the first time to review and validate the research Visual Impairment Intracranial Pressure (rVIIP) draft research plan. Data mining activities that analyze existing ground and flight data for trends and contributing factors related to VIIP will be completed in early 2012, and a new effort to collect additional in-flight data will begin. New rVIIP research selections from the NRA are expected to start in mid-year and new technologies for non-invasive intracranial pressure measurement, ocular coherence tomography, and ultrasound image analysis will be assessed.

In addition, the Human Health Countermeasures (HHC) Element will complete the final in-flight session for the VO2Max experiment designed to quantify the risk of reduced physical performance capabilities due to reduced aerobic capacity. New studies will be initiated to evaluate which countermeasures are the most efficient to counteract decreases in bone strength and facilitate astronauts return to normal one year following a six-month flight on ISS and whether there is an increased risk of disease in the blood vessels in astronauts during and following six months of spaceflight.

ExMC to Initiate Exploration Medical System Demonstration Test Bed Project on ISS

The Exploration Medical Capabilities (ExMC) Element will initiate development of the Exploration Medical System Demonstration (EMSD) project. The ESMD will be a test bed on the International Space Station (ISS) to demonstrate an end-to-end medical system to assist the Crew Medical Officer (CMO) in optimizing medical care delivery and medical data management during missions. The

system will demonstrate the integration of medical technologies and medical informatics tools for managing evidence and decision making. The ESMD includes components such as: assisted medical procedures, consumables tracking, in-flight integrated medical model, electronic medical records, dry electrodes, flexible ultrasound, and video conferencing.

SHFH Element Delivers Final Lunar Dust Permissible Exposure Limit

The Space Permissible Exposure Limit (SPEL) is a quantifiable limit of exposure to a space flight factor over a given length of time – such as lifetime radiation exposure. SPELs are also developed for physical and chemical agents that can be measured. In FY2012, the Space Human Factors and Habitability (SHFH) Element will deliver a refined Lunar Dust PEL. In addition, the final assessment of dermal toxicity of lunar dust will be completed with recommendations on how dermal irritations from lunar dust could be minimized or avoided.

Also in FY2012, the SHFH Advanced Food Technology Project plans to complete the food processing versus packaged food system trade study. Results from this study will drive requirements for future exploration missions. Finally, the Space Human Factors Engineering Project will finalize the results of the Habitable Volume Workshop and develop a research plan to understand minimum habitat volumes for deep space vehicles.

BHP Investigators to Deliver New Non-Invasive Technologies to Monitor Stress and Fatigue

The NSBRI has several Behavioral Health and Performance (BHP) investigators completing their technology developments in the areas of Optical Computer Recognition of stress, Sleep/Wake Actigraphy, and light optimization strategies. Several SBIR efforts are planned in FY2012 to complete ground assessments of technologies to monitor cognitive function and team interactions, and University investigators plan to complete development of innovative training techniques that enhance team performance.

An ISS Expedition 26 crew member peeks out of her sleeping quarters. Studies have shown that astronauts typically sleep 0.5 to 2.5 hours less than they do on Earth. BHP develops tools to optimize the crew's work and rest schedules.

HRP Fiscal Year At A Glance

FY12

Programmatic Accomplishments

Technical Accomplishments

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Program Mtgs & Reviews

- Russia/NASA JWG
- ISLSWG, San Francisco
- HRP Investigators' Workshop
- CAMMEE Directed task review meeting
- Train Like an Astronaut Closing Event
- Program Status Review Visit

Solicitations

- SBIR 2010/2 Selections
- SBIR 2011/1 Selections
- Radiation NRA Release
- 2011 NASA/NSBRI NRA Selections
- 2012 NASA/NSBRI NRA Announcement
- Radiation Selections

Documentation/ Tools

- HRP Annual Report
- Program Plan Rev. B
- IRP/HRR Update

ISS Medical Project

- 28S
- 29S
- 30S
- 31S
- Space X 1st Launch
- 32S

Behavioral Health & Performance

- NEEMO15 Comm Delay
- Sleep-Wake Actigraphy Study Final Report

Exploration Medical

- Therapeutic U/S Prototype

Human Health Countermeasures

- FTT Report & Rec. to Space Medicine
- Bisphosphonates reduce bone loss Prelim. Rec.

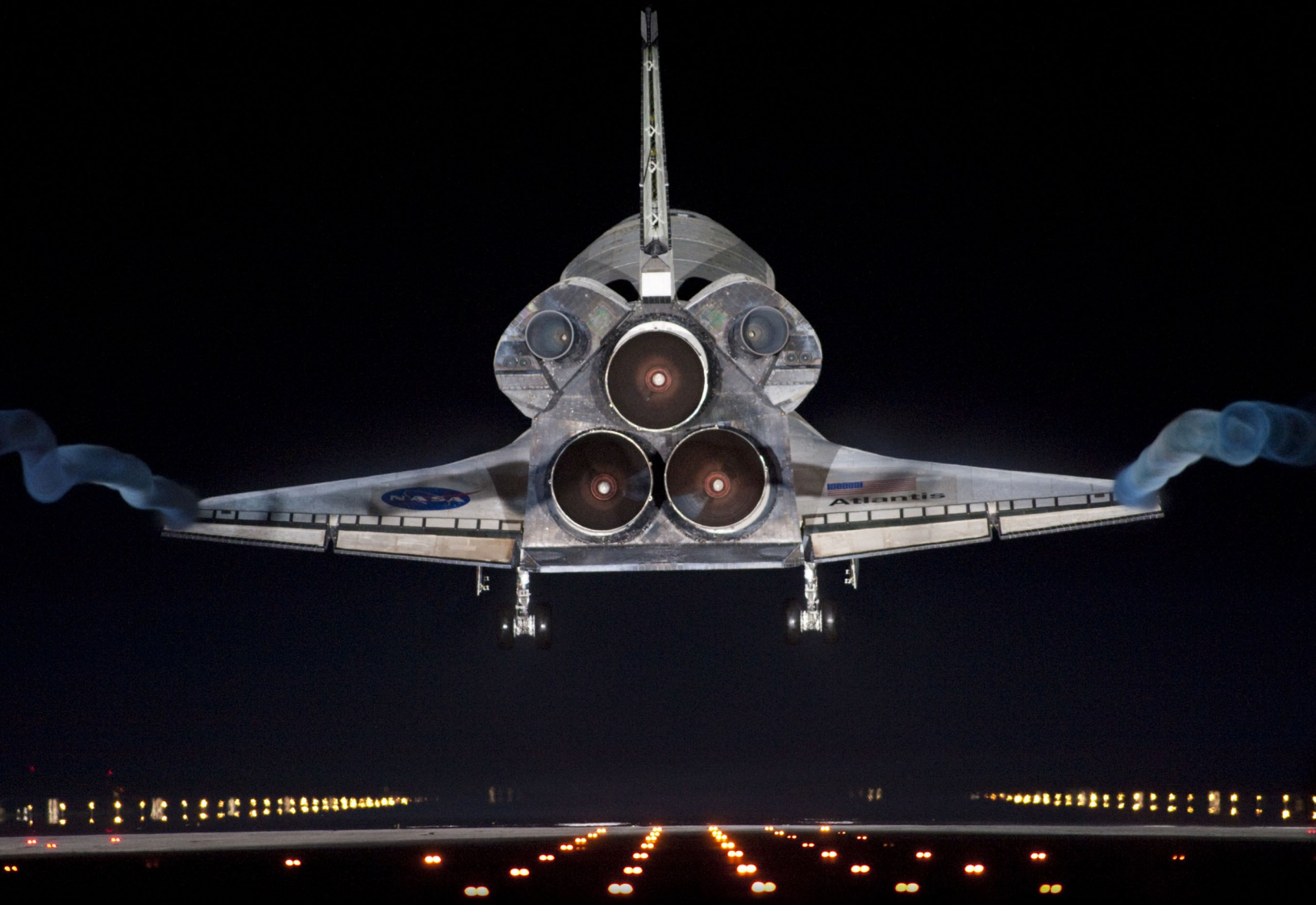
Space Human Factors

- NEEMO 15 Hab Assessment
- Final Lunar Dust PEL
- HIDH Technical Update
- Function Allocation SW tool delivery

Space Radiation

- Vehicle Shielding Design Tool
- Acute Risk Model v2

RED OUTLINE DESIGNATES USE OF ISS



Human Research Program

2011 Fiscal Year Annual Report

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http://www.nasa.gov/exploration/humanresearch
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